SPECIES DIVERSITY AND ECOLOGY OF TRICHOPTERA (CADDISFLIES) AND PLECOPTERA (STONEFLIES) IN RAVINE ECOSYSTEMS OF NORTHERN FLORIDA

By

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SPECIES DIVERSITY AND ECOLOGY OF TRICHOPTERA (CADDISFLIES) AND PLECOPTERA (STONEFLIES) IN RAVINE ECOSYSTEMS OF NORTHERN FLORIDA

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Species diversity and ecology of insects within the orders Trichoptera (caddisflies) and Plecoptera (stoneflies) were investigated in ravine streams of northern Florida. Ravine ecosystems in Florida are known to support diverse biota, including northern elements and endemic species, but little information concerning stream insects was known. This study is the first to collect stream insects systematically from ravine drainage networks across northern Florida. From West to East, the areas surveyed included streams on Eglin Air Force Base, streams within the Apalachicola and Ochlockonee river basins, and a stream located in peninsular Florida. Caddisfly and stonefly species diversity was investigated at 29 stations along both upper- and lower stream-reaches. Adult and immature insects were collected and identified, and these data were used to characterize caddisfly and stonefly species diversity and adult flight

seasonality. Adult emergence phenology at a ravine springrun was further investigated using emergence traps.

The survey results, based on more than 16,500 specimen identifications, document a diverse fauna of 138 species of Trichoptera and 23 species of Plecoptera. More than 50 species are either ravine-habitat specialists, endemic to small areas of the lower Coastal Plain, or are disjunct from northerly geographic ranges. Sixteen species recorded are listed by the Florida Committee on Rare and Endangered Plants and Animals as Threatened or Rare. At least 12 caddisfly species previously unknown to science were discovered, and 11 of these have subsequently been described and named. Steephead ravine streams in the western panhandle contain a highly endemic fauna, and the ravine fauna of the central panhandle streams has the strongest Appalachian affinities.

In order to quantify faunal similarities among stations, cluster analysis was performed on the survey data for macrocaddisfly species collected at 20 stations. Based on the resultant dendogram, 5 macrocaddisfly communities were recognized among the streams sampled. Communities appear to be hierarchically structured according to biogeographic region at a large scale, and by habitat factors related to stream size and ravine type at a smaller scale. Results of detrended correspondence analysis of the same data set supported these conclusions.

CHAPTER 1
INTRODUCTION

With a budding interest in aquatic entomology and lured by the natural beauty and mystery of ravine springruns, I undertook an investigation into the species diversity and ecology of aquatic insects that live in these systems. After more than 10 years of research, I am pleased to present findings concerning 2 important aquatic insect groups: Trichoptera and Plecoptera. The following dissertation on the topic is organized by chapters: Chapter 1 introduces the subject matter, Chapters 2, 3, and 4 address major research objectives, and the final chapter (Chapter 5) provides a summary of the study and conclusions. The specific objectives of this introductory chapter are to i) provide a biogeographic context to the study; ii) present a general characterization of ravine ecosystems in northern Florida; iii) outline the major research objectives; and iv) describe the study areas.

Biogeographic Context

Taxa Considered

Trichoptera and Plecoptera, commonly known as caddisflies and stoneflies, respectively, are diverse and ecologically important orders of aquatic insects. Trichoptera are the largest order of primarily aquatic insects—globally containing over 11,000 nominal species and subspecies (Morse, 2003). In North America, more than 1300 caddisfly species have been reported (Morse, 2003), and approximately 200 of these are known in Florida (Rasmussen, unpublished data). Plecoptera are a smaller order,

containing about 2000 described species worldwide (Stewart, 2003), approximately 600 species in North America (Stark et al., 1998) and 40 species in Florida (Rasmussen et al., 2003).

Almost all caddisfly and stonefly species are confined to aquatic habitats during their immature life stages (Wiggins, 1996; Stewart & Stark, 2002) and occur terrestrially only during the relatively short-lived adult stage. Because of this aquatic dependence, environmental conditions and the resources present in aquatic habitats are critical factors influencing their biodiversity and evolutionary history; both groups are widely used by environmental regulatory agencies as bioindicators to assess water quality. Caddisflies and stoneflies are especially diverse and abundant in cool running-waters, where they are often dominant members of benthic macroinvertebrate communities.

Much of the caddisfly and stonefly fauna found in eastern North America is endemic to the region and has evolved in concert with eastern deciduous forests. This is particularly true in headwater streams, where the caddisfly and stonefly faunas consist largely of species ecologically adapted and confined to those habitats, as compared to river faunas, which contain a higher percentage of widespread ecological generalists (Ross, 1963). The ecology of benthic communities in headwater streams is intimately linked with that of the terrestrial biomes in which they occur. Riparian forests, in particular, have a great impact on the physical, chemical, and biological characteristics of streams—the degree to which is inversely related to stream size (Vannote et al., 1980). In northern Florida and other areas of the Southeastern Coastal Plain, many caddisfly and stonefly taxa adapted to headwater woodland streams reach their southern range-limits

and have discontinuous peripheral populations corresponding to the patchy distribution of equitable habitats.

Crenobiology

Streams at their source often begin as springs. The zone that includes the spring source and downstream springrun (springbrook) is known as the crenal zone (Ward, 1992). It represents a well-bounded area with distinct biotope—the study of which is addressed by a branch of aquatic ecology known as crenobiology. The caddisfly and stonefly communities investigated in this study occur largely in crenal habitats; therefore, their study falls under the discipline of crenobiology. Groundwater feeding the ravine streams studied in this project comes from spring boils, as well as more diffuse seepage springs along bank areas. Together, these sources produce a springrun (rheocrene).

Crenal ecosystems are attractive to ecologists because they are discrete and relatively stable in terms of abiotic conditions at their sources, but exhibit departures along various environmental gradients within the springrun. Crenobiological research in large artesian springs has resulted a number of comprehensive investigations into trophic structure and community ecology. In peninsular Florida, 2 classic studies were carried out at Silver Springs (Odum, 1957) and Homosassa and Weekiwachee springs (Sloan, 1956). Within temperate eastern North America, a number of influential studies have been conducted on smaller springruns (e.g., Minckley, 1963; Minshall, 1968; Tilly, 1968). Besides ecologists, crenal habitats are also of interest to zoogeographers because they are refugia for relict populations of once widespread species. On the applied side, crenobiology can be used in the biological assessment of groundwater quality. The continued interest in crenobiology and a trend towards focusing on invertebrate biodiversity is reflected in the

papers published recently in 3 large edited-works, namely, Williams and Danks (1991); Ferrington (1995); and Botosaneanu (1998).

Northern Florida: "Hot Spot" of Biodiversity

As a result of many interrelated factors, areas on our planet differ greatly in terms of biodiversity. Past and present climate, geography, and geology play major roles in shaping biomes and component biota. Availability of water, a requirement that connects all life, is a key resource that influences the biota characteristic of a particular place. Generally, land areas with the greatest and most unique biological diversity lie in regions with benign climates and plentiful freshwater resources, and are geographically isolated areas containing unique habitats with corresponding selective pressures. The panhandle region of northern Florida satisfies all these criteria, and, not surprisingly, is a "hot spot" of biodiversity considered to be among the top 5 regions of the continental United States in terms of having the highest concentration of plant and animal species with restricted distributions (Chaplin et al., 2000). Although the lower Coastal Plain occupied by northern Florida is recognized for its rich biodiversity, there are still many invertebrate groups for which little is known. It is within these groups that the vast majority of unknown biodiversity remains to be discovered.

Florida's diverse natural setting has been characterized in many publications. Excellent general accounts of climate, soils, and overviews of the many different aquatic and marine ecosystems, as well as terrestrial upland systems in Florida, were provided in *Ecosystems of Florida* (Meyers & Ewel, 1990). A comprehensive atlas summarizing Florida's water resources is found in Fernald and Purdum (1998), and surface water resources as they relate to fisheries were covered in Seaman (1985). Papers detailing the

biodiversity of aquatic communities in Florida and the southeastern U.S. were presented in Hackney et al. (1992). Publications focusing on the natural history of the Florida panhandle include a general ecological characterization given by Wolfe et al. (1988), and a thorough accounting of the natural setting and plant communities presented in Clewell (1981).

Much of Florida's unique species diversity is documented in a series of publications titled *Rare and Endangered Biota of Florida*. In these publications, the Florida Committee on Rare and Endangered Plants and Animals (FCREPA) provides species lists and documentation for species considered to be endangered, threatened, rare, or species-of-special-concern within the state (Deyrup & Franz, 1994). As a result of new data collected in this study, there are a number of additional species that are excellent candidates for inclusion into future conservation listings; in Chapter 2 these species are identified. It is through documenting and tracking species-at-risk that conservation efforts will be most effective (Bossart & Carlton, 2002).

Historical Biogeography

The biogeographic history of Florida has been well documented. Publications presenting general overviews included those of Neill (1957), James (1961), and Webb (1990). Biogeographers concentrated to a great extent on Florida in attempting to reconstruct the vegetational history of the Southeastern Coastal Plain during the Pleistocene and Holocene. Important works included those of Delcourt and Delcourt (1977; 1984), Watts (1980), Watts and Stuiver (1980), Watts et al. (1992), Platt and Schwartz (1990), and Schwartz (1994). These studies support the assertion that the faunal and floral composition of northern Florida has fluctuated throughout the Pleistocene and

Holocene in concert with climatic fluctuations and concomitant changes in temperature, rainfall, and sea-level stands.

Major rivers draining the Southeastern Coastal Plain apparently served as important corridors through which organisms moved in response to the climate changes experienced during the Pleistocene and Holocene. Delcourt and Delcourt (1975; 1984) postulated that mixed-mesophytic forest species migrated southward onto the Coastal Plain during the late Pleistocene fostered by the moist conditions the rivers supplied to the adjoining uplands. They concluded that dissection of these uplands into ravines with suitable environmental conditions has resulted in the continued relict existence for many northern plant species. By extension, this scenario can be used to account for the distributional history of aquatic fauna associated with mixed-mesophytic forest, of which many caddisfly and stonefly taxa are included.

It is likely that major North/South movements in biota occurred multiple times during the various glacial and interglacial periods, suggesting that the origins of present-day biota are multiple and complex. Hamilton and Morse (1990) investigated origins and affinities of the caddisfly fauna of the southeastern United States and found that most Coastal Plain endemics are more closely related to species further North and that very few endemics have sister lineages endemic to the Coastal Plain. Hamilton and Morse (1990, page 597) went on to infer that "the endemic Southeastern Coastal Plain caddisfly fauna had multiple origins, perhaps the result of numerous peripheral isolations of ancestral taxa resulting from fluctuating climates and possibly associated sea level oscillations."

Coastal Plain Ravines as Refugia

By affording cool-adapted or stenothermal organisms the requisite environmental conditions for survival, ravine habitats of northern Florida are present-day and historical refugia for organisms unable to survive the harsher conditions present in predominant habitats of the surrounding landscape. Besides containing disjunct northern elements, ravines are also known as areas of endemism. With enough time, populations isolated within ravine habitat-islands can speciate as a result of founder effects and local selection pressures. The opposite phenomenon (homeostasis) can also occur, whereby ancestral species or species representative of relict communities are preserved. In this sense, investigations of ravine biota can be informative in reconstructing historic faunal and floral compositions.

Neill (1957), in discussing origins of Florida's biota, references many of the early works that describe northern Florida biota and distinctive elements of ravine habitats. Neill (1957, page 185), noting that both northern elements and endemics are clustered around the Apalachicola region and western panhandle, hypothesized that many of these species were, "typical, widely ranging, Gulf Coast forms at a time when the climate was cooler and wetter than at present." He presented as evidence for this hypothesis examples of species that have discontinuous distributions on the Gulf Coastal Plain.

The most well known ravine-refugium within northern Florida is the Apalachicola Bluffs and Ravines region, often referred to as "Torreya" in reference to a relict conifer, *Torreya taxifolia* Arn., that is largely confined to the region. In describing the area's uniqueness, Hubbell et al. (1956, pages 20-21) stated:

> Although physiographically it is no more than the dissected edge of the upland, biotically it may be regarded as a small but distinctive natural region characterized

> by its peculiar mixture of Coastal Plain and northern plants and animals, and by the presence of a group of remarkable relic species restricted to the region. Some of its peculiarities were pointed out by Croom as long ago as 1833-1835 and Asa Gray (1875) made the region famous by his paper, "A Pigrimage to Torreya".

J. Speed Rogers was among the earliest zoologists to characterize streams of the Torreya ravines and to document the uniqueness of the aquatic fauna. Rogers (1933, page 25), in his monograph describing cranefly distributions and habitats in northern Florida, wrote of the ravines:

> Small sandy bottom brooks flow along these ravines and often pass into short swampy reaches where they wander through tangles of standing and fallen vegetation and over deposits of rich organic silt. Near the bottom, springs and seepage areas are common and wet rotten wood, fungi, mosses and liverworts are abundant.
>
> The fauna of these ravines is as surprising and interesting as their flora, for here a number of animals reach their southernmost limits, frequently disjunct from the remainder of their ranges. In the Amphibia, Crustacea, Odonata, Ephemerida and Orthoptera a number of unexpected, northern species or species with distinct northern affinities have been discovered and among the crane-flies more than a dozen species are found that have been taken nowhere else south of the Piedmont region.

Ravine Ecosystems of Northern Florida

When trying to understand the diversity of organisms found in a specialized habitat more fully, it is prudent to consider the general physical, chemical, and biological characteristics of that habitat, as they are likely to exert considerable controls on community composition and ecology. The following discussion provides a general backdrop to the natural settings of the ravine ecosystems studied.

Ravine Geomorphology and Distribution

The stream systems studied occur in upland areas of northern Florida where erosional processes have dissected the uplands to create headwater ravines and valleys in sharp contrast to the low-relief landscapes found throughout much of the Southeastern

Coastal Plain. Ravines are steep-walled drainage networks formed both by erosion from surface-water runoff and groundwater spring-flow. They are found in higher elevation landforms (>50 m above mean sea level) and are often associated with river escarpments. Topology and geomorphologic characteristics are discussed below. An account of ravine distribution in the Florida panhandle is provided in Wolfe et al. (1988).

Steephead ravines

In landforms having high infiltration rates and large surficial-aquifer storage capacities, as in areas with deep deposits of coarse sands, overland surface erosion is low, and ravine formation is controlled by groundwater processes (Schumm et al., 1995). Under these conditions, groundwater sapping causes headward erosion of overlying deposits to form linear valleys that have steep amphitheatre-shaped heads. Ravines of this type are known as "steepheads" and were first described by Sellards and Gunter (1918). Steepheads are considered to be a geologic formation unique to northern Florida. Steephead drainage networks have relatively low stream-densities (ratio of channel length to drainage area), as compared to other drainage networks (Schumm et al., 1995), and because of permeable soils, surface drainage lines connecting the plateau and ravine bottom are generally absent. Steephead drainage networks tend to have a trellis pattern as a result of tributary steepheads forming perpendicular to the main drainage axis. Headwall slope is typically 45 degrees or greater, and depth at the head is often greater than 30 meters.

Schumm et al. (1995) suggested that steephead advance is episodic and is promoted by loss of vegetation on upslopes or prolonged wet periods, and that movement is halted through groundwater capture by adjacent watersheds. Contrary to the widely accepted

fact that steephead spring-flow emerges along a relatively impermeable confining clay layer, Schumm et al. (1995) reported finding no paleosol or hardpan in drilling at the base of 2 steepheads on Eglin Air Force Base. This evidence and support from experimental studies indicate that a low permeability horizon is not a requirement for steephead formation (Schumm et al., 1995).

Steepheads in the panhandle are distributed below the Cody scarp in an east-to-west trending line, where it appears that late Pliocene/early Pleistocene deposits of coarse sands formed coastal sand dunes and barrier islands during higher sea level stands. Two areas within the Florida panhandle that possess excellent examples of steephead complexes are in the western panhandle near the coast on the western side of Eglin Air Force Base (southern portions of Santa Rosa and Okaloosa counties) and in the central panhandle associated with the Apalachicola River escarpment and Sweetwater Creek (Liberty County). Steepheads occur also in several other panhandle locations (see Means, 1975), as well at a few scattered localities on upland sand ridges of the northern Florida peninsula.

Clayhill ravines

In rolling clay hills and along river escarpments having tightly-packed upland soils, rainfall rates often exceed infiltration rates and scouring from surface runoff results in the formation of what I will term “clayhill” ravines, a reference to the clay content of the soils and the name given to the associated mesic upland community-type. Another term used to describe this type of ravine is “gully-eroded” (see Wolfe et al., 1988; Means, 2000). The drainage networks of clayhill ravines are typically dendritic and have higher stream densities and variablity in stream flow as compared to steephead networks. Stream

flow fluctuation in these systems, however, is often moderated by groundwater flows along ravine walls and bottoms in the form of small springs and diffuse seepage; thus, substantial groundwater inputs result in many streams having permanent spring-fed baseflows. Drainage lines generally originate along the upper slopes and form v-shaped gullies. In areas of groundwater sapping, sharp vertical cuts of the overburden may also occur. Slopes of clayhill ravine-heads and sidewalls are generally less than 30 degrees. Clayhill ravines occur in upland landforms of the Florida panhandle above the Cody scarp, where soils are primarily composed of Miocene-age clastics. Some of the most well developed clayhill ravines lie within the Tallahassee Red Hills–Tifton Uplands region in northern Gadsden and Leon counties of Florida and adjacent counties of Georgia.

Plant and Animal Communities

The terrestrial plant and animal communities of ravine ecosystems in northern Florida contain a diverse mix of northern, warm temperate, and endemic elements. An accounting of this biodiversity is far from complete, and what is known is reported across many publications. A general treatment of some of the distinctive and major components of ravine flora and fauna is presented in Wolfe et al. (1988). Other publications dealing with plant and animal communities of ravines include a biological survey of the Apalachicola ravines by Leonard and Baker (1982) and a natural community survey of Eglin Air Force Base by Kindell et al. (1997).

Mixed-species hardwoods are the most conspicuous component of ravine flora, and these have been studied at a number of ravine systems across northern Florida (Clewell, 1981; White & Judd, 1985; Platt & Schwartz, 1990; Gibson, 1992; Kwit et al., 1998).

The very high density of different tree species occurring in ravines is accounted for by the habitat diversity associated with gradients in elevation and soil moisture—proceeding from xeric conditions of the ridge tops down through mesic mid-slopes to the hydric conditions of the ravine bottom. Ravine forests typically contain oaks and hickories on upper slopes, grading into mesic hardwoods (e.g., American beech, southern magnolia, American holly) on midslopes, and a swamp forest community (e.g., swamp bay, sweet bay, black gum) on hydric lower-slopes and ravine bottom. In panhandle ravines, Florida star anise is an abundant understory species growing in saturated soils around springhead areas. Sphagnum, other mosses, liverworts, and ferns are abundant in ravine bottoms, which typically contain rich accumulations of leaf litter and humic soils. Much of the faunal diversity of ravine ecosystems occurs on the forest floor and is associated with the deep layer of leaf litter and other organic matter that serves as a food base for countless arthropods and other invertebrates, which in turn support a far lesser number of small vertebrates (e.g., salamanders) that feed on them.

Stream Characteristics

Because of spring-flow inputs from surficial-aquifer sources, ravine streams in northern Florida are typically perennial and rather uniform in terms of many of their physical and chemical characteristics. In general, the streams are clear, cool, somewhat acidic, and low in nutrients. As compared to steephead streams, clayhill ravine streams tend to have more variable hydroperiods and episodes of high turbidity due to greater amounts of surface runoff and scouring after rain events. In steephead drainage networks, the high infiltration rates and storage capacity of the surrounding landform result in minimal runoff. Steephead springruns, over relatively short distances, can have rather

sizeable flows. Third order steephead streams discharge water at rates as high as 100 ft^3 sec^{-1}. By comparison, the baseflows of clayhill ravine streams typically are far less, even as 5^{th} or 6^{th} order streams.

As water flows downstream from the ravine head, water temperature fluctuations increase due to ambient cooling and warming. The streams with narrow- and deep channels, typical of steephead springruns, tend to maintain more constant temperature conditions, as compared to the shallower and less voluminous streams in clayhill regions, which may experience significant warming in summer. High-temperature extremes can adversely affect organisms adapted to spring-fed woodland streams and may preclude them from living in these systems.

Benthic organisms such as caddisflies and stoneflies find a wide range of suitable substrates in ravine streams on which to live. The stream bottom at the ravine-head typically contains an abundance of coarse woody debris, including leaves, sticks, and logs. Also, ravine-head mineral substrates tend to be diverse, and there often occurs pea-gravel, pieces of clay or marls, as well as coarse sand. The stream from the ravine head typically arises from multiple, small spring-boils and rivulets that merge to form a main channel that then flows through the densely vegetated ravine bottom. Numerous depositional areas of silt and organic muck are also common in the ravine heads and upper reaches. The stream gradient is usually not great and appears to follow the slope of the water table in most ravines systems. Debris dams can form small waterfalls in places. Down from the ravine head, streams may meander through mesic forest or in some systems may flow through swamp forest within a braided channel. At 3^{rd} order and

higher, streams typically have a well-defined channel with snags and undercut banks providing much in the way of productive benthic habitats.

Project Objectives and Scope

Given the lack of information concerning Trichoptera and Plecoptera biodiversity in ravine ecosystems in northern Florida and the high potential for these organisms to be important and diverse biotic components of the stream ecology, the following research objectives were set:

i) inventory species diversity of Trichoptera and Plecoptera in ravines ecosystems of northern Florida.

ii) characterize caddisfly and stonefly species occurrences in terms of geographic distributional patterns, species/habitat associations, and distinctive faunal elements.

iii) investigate caddisfly community structure and distributional dynamics in relation to geographic and habitat parameters.

iv) characterize caddisfly and stonefly flight seasonality.

v) investigate emergence of adult caddisflies and stoneflies from a ravine springrun.

This study is essentially descriptive in scope and purpose. The stream systems studied represent several major river drainages and regions of northern Florida, and the survey points encompass ravine streams from their upper-most headwaters through lower stream-reaches. It is the first comprehensive study to describe and compare stonefly and caddisfly biodiversity at several different areas on the lower Coastal Plain possessing ravine drainage networks. I wish to stress though that faunistic studies of yet-unexplored ravines will likely uncover important new information concerning species diversity and community structure.

Description of Study Areas

Caddisfly and stonefly species diversity and ecology were investigated within northern Florida at 4 different study areas (Fig. 1-1). The areas studied span much of northern Florida and thus represent different major drainages and regions of Florida. Three of the study areas lie within the Florida panhandle on the Eastern Gulf Coastal Plain: the Eglin study area within the western Florida panhandle, and the Apalachicola and Florida A&M University (FAMU) Farm study areas within the central panhandle region. The Gold Head study area is located on the northern Florida peninsula. Present among the study areas are relatively pristine examples of both steephead and clayhill ravines from which a wide range of different stream habitats were sampled. A description of the study areas and sampling stations is given below.

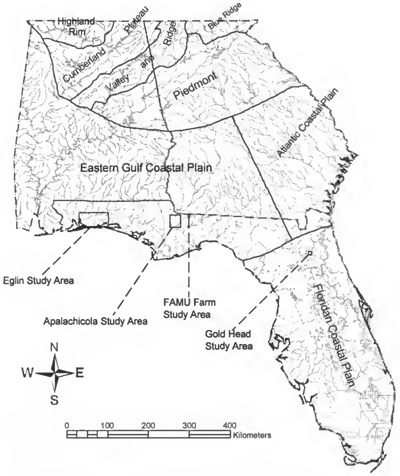


Figure 1-1. Study areas in relation to drainages and physiographic provinces of Alabama, Georgia, and Florida.

Eglin Study Area

The Eglin study area (Fig. 1-2), largest of the 4 study areas, is located on the western side of Eglin Air Force Base in a region where there is an extensive steephead drainage network incised into uplands comprised largely of xeric sandhill community containing large tracts of longleaf pine (*Pinus palustris* Mill.). The streams sampled feed 2 major drainage basins, the Yellow River basin and the Choctawhatchee Bay basin. A wide array of stream habitats is represented at the 12 stations sampled, ranging from small, ravine-head springruns (Stations E1, E3, E5) to lower stream segments with considerable discharge (25-100 $ft^3 sec^{-1}$) (Stations E4, E8, E9, E12). Transitional in habitat between upper steephead reaches and lower downstream reaches were middle-reach stations (E2, E6, E7, E10, E11). Eglin's steephead streams, because of heavy spring-inputs and relative little surface runoff due to the highly permeable sands of the area, maintain springrun characteristics in terms of stable flow and temperature regimes and high clarity throughout their lengths.

At middle and lower reaches on Eglin's steephead streams, aquatic macrophytes are particularly abundant, especially in wider stream-segments having relatively open canopies. Some of the most common aquatic plants encountered along the clear and deep springruns within the Eglin study area are *Eriocaulon decangulare* (L.), *Juncus repens* (Michx.), *Eleocharis* spp., *Orontium aquaticum* (L.), *Sagittaria* spp., and *Vallisneria americana* Michx (Theresa Thom, personal communication). Plants that are typically emergent such as *Eleocharis* and *Juncus repens* (Michx.) often grow densely and completely submerged in the clear waters. The freshwater red alga, *Bactrachospermum* sp., is also very abundant at lower reaches.

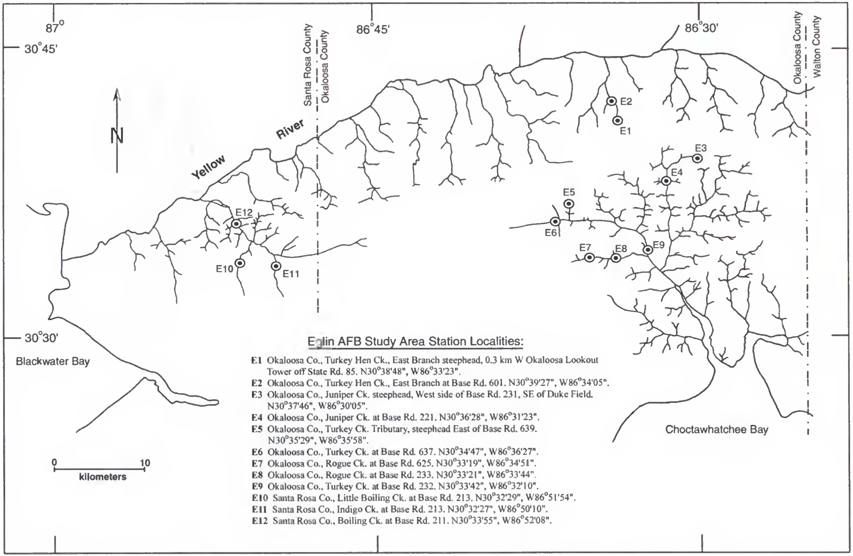


Figure 1-2. Eglin study area and locations of collecting stations. The study area is located in the western portion of Eglin Air Force Base.

Apalachicola Study Area

The Apalachicola study area (Fig. 1-3) is located in the central Florida panhandle on the east-side of the upper Apalachicola River in a region known as the Apalachicola Bluffs and Ravines, sometimes referred to simply as "Torreya." The drainage network of the region is associated with the Apalachicola/Flint river escarpment with all streams flowing towards the lower elevations of the river's floodplain. A well-developed drainage network comprising both steepheads and clayhill ravines has extensively dissected the uplands to create an area with some of the sharpest relief on the Southeastern Coastal Plain. Fortunately, a significant portion of the study area (about 8000 hectares) is currently either within Torreya State Park or is under the stewardship of The Nature Conservancy. Thus, conservation efforts and the prospects of preserving the area's rich natural history are promising.

Within the study area are many small headwater streams as well as higher magnitude (4^{th}-6^{th} order) streams such as Flat, Crooked, and Sweetwater creeks. Sampling stations, representing a wide array of stream habitats, were established at 12 locations. Steephead ravines occur predominately within the sandhill community in the southern portion of the study area south of the main axis of Sweetwater Creek, on which station A6 is located. Six sampling stations were within this area, including 3 upper-reach sites (A8, A9, A11), 2 stations further downstream on the springruns near where they enter the river floodplain (A7, A10), and 1 station within a short isolated-ravine, very near to where its small stream cascades into the Apalachicola River (A12). Within the more mesic clayhill-uplands of the northern part of the study area, headwater reaches were sampled at 2 stations (A3, A5), and larger streams were sampled at 4 stations (A1, A2, A4, A6). The

larger streams, as a result of land/water interactions, generally have higher pH (circumneutral) and more variable conductivity, turbidity, and temperature, as compared to the headwater streams in which values for these parameters largely mirror spring-flow inputs.

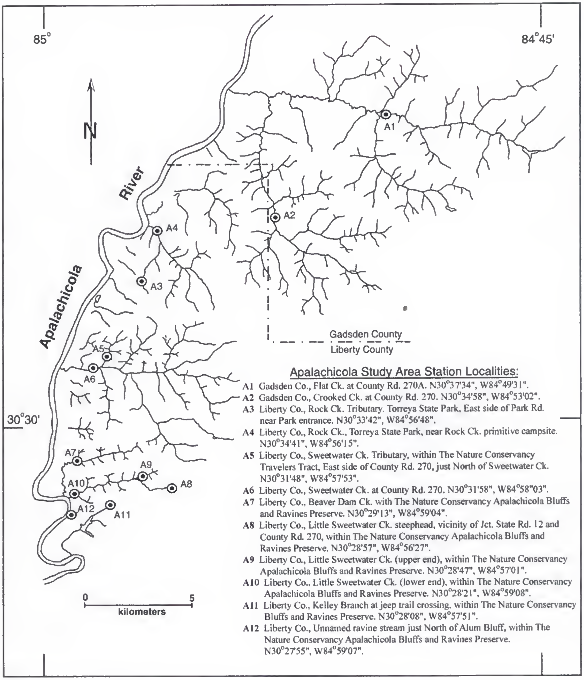
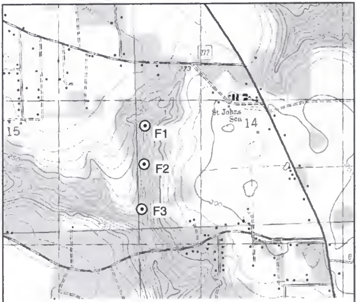


Figure 1-3. Apalachicola bluffs and ravines study area and locations of collecting stations.

FAMU Farm Study Area

The FAMU Farm study area (Fig. 1-4) is located in the central panhandle within Ochlockonee River basin. The ravine system studied bisects property owned by Florida A&M University, which serves as an agricultural research and extension center for the university. The ravine is in a relatively natural state, and because of university ownership, offers excellent opportunities for studies of the associated hardwood hammock and spring-fed stream. Collecting for the survey was conducted at 3 stations on this 1st-order stream. In addition, emergence traps were placed over the stream at 2 locations near station F1. The results of the emergence study are reported in Chapter 4. The ravine springrun is a headwater for Quincy Creek, a tributary of the Little River, and part of the larger Ochlockonee River Basin, which drains portions of the central Florida panhandle and southern Georgia. The ravine is relatively shallow (≈ 15 m) as



CONTOUR INTERVAL 10 FEET 0 1000 meters

N

FAMU Research and Extension Center (REC) Study Area Station Localities:

F1 Gadsden Co., Quincy Ck., headwater stream (upper reach), FAMU REC, County Rd. 267, 7 km North of Quincy. N30°39'27", W84°36'50".

F2 Gadsden Co., Quincy Ck., headwater stream (middle reach), FAMU REC, County Rd. 267, 7 km North of Quincy. N30°39'19", W84°36'51".

F3 Gadsden Co., Quincy Ck., headwater stream (lower reach), FAMU REC, County Rd. 267, 7 km North of Quincy. N30°39'12", W84°36'56".

Figure 1-4. Florida A&M University Research and Extension Center study area and locations of collecting stations. Map taken from USGS 7.5 minute Dogtown quadrangle.

compared to sandhill steepheads, which can be over 30 meters deep. Within the ravine hammock is a diverse mix of mainly hardwood species including deciduous trees such as American beech (*Fagus grandifolia* Ehrh.), oaks (*Quercus* spp.) and hickories (*Carya* spp.), as well as evergreen species including *Magnolia* spp., mountain laurel (*Kalmia latifolia* L.) and Florida Star Anise (*Illicium floridanum* Ellis), which is the dominant shrub species in the ravine bottom. Land use in the immediate vicinity is mainly agricultural (planted pine and pasture) and residential.

The springrun is formed by spring flow issuing from small springs and diffuse seepage throughout the ravine. Water is somewhat acidic (mean pH 5.6) and low in alkalinity (≈ 2 mg $CaCO_3$ L^{-1}) with a mean conductivity of 39 µmhos cm^{-1}. The water temperatures in the upper sections of the springrun are relatively constant, maintaining a temperature between 18.4 and 21.4°C year-round. The springrun averages about 1 meter in width and in most places is less than 10 cm deep; average water velocity is 0.3 m sec^{-1}. Because of shallow somewhat turbulent flows, the springrun is well oxygenated, with oxygen levels averaging about 80% of total saturation.

Gold Head Study Area

The Gold Head study area (Fig. 1-5) is located in northeastern Florida at Mike Roess Gold Head Branch State Park (Clay County) within the lower St Johns River basin. The stream for which the park is named, Gold Head Branch, originates in a steephead ravine that dissects the southeastern edge of a sand-ridge known as the Trail Ridge. The uplands around the ravine hammock comprise primarily xeric sandhill community. White and Judd (1985) documented an extensive flora of some 356 plant species, representing 5 communities, in the Gold Head ravine and adjacent upland. Besides Gold Head Branch,

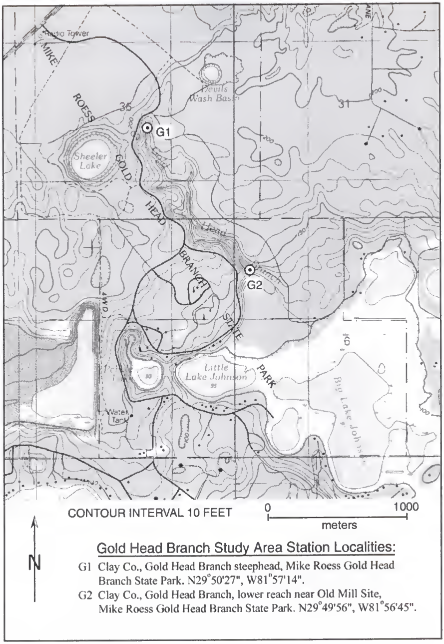


Figure 1-5. Gold Head Branch study area and locations of collecting stations. Map taken from USGS 7.5 minute Gold Head Branch quadrangle.

other waterbodies in the area include several sinkhole and sandhill lakes. Close to the ravine head is Sheeler Lake, a deep and very old sinkhole lake (about 24,000 yrs old) that is a well-known and important palynological site (see Watts and Stuiver, 1980). Gold Head Branch was sampled at 2 stations, Station G1 at the head of the ravine and Station

G2 near the end of the ravine just above the point at which the stream valley widens into a delta and the stream enters a flatwoods and basin marsh before flowing into Lake Johnson. Unlike the other ravine streams studied, Gold Head Branch terminates at a lake and is more isolated in this sense than the other stream sites studied, which were all part of larger stream networks. Many small spring-boils and extensive seepage occur at the ravine head, consequently the stream rapidly gains flow within its first 50 meters. Flow levels for Gold Head Branch, as reported in the Park Management Plan, ranged from 34,077 gallons per hour to 56,520 gallons per hour. As is typical of ravine springruns in northern Florida, water temperature stays within a narrow range, the water is somewhat acidic, and has low conductivity. Recent measurements taken near station G2 during several times of year by the Florida Department of Environmental Protection ranged as follows: pH (4.6-6.6), water temperature (17.4-23.5°C), specific conductance (16-34 μmhos cm^{-1}) (Lee Banks, personal communication).

CHAPTER 2
TRICHOPTERA AND PLECOPTERA BIODIVERSITY SURVEY

As noted in Chapter 1, ravine ecosystems in northern Florida have been well documented in terms of their vegetation and geomorphology, but knowledge of ravine faunas, especially aquatic insect groups, is relatively incomplete. This study, an investigation into caddisfly and stonefly biodiversity, is the first in which aquatic insects were systematically collected from headwater and downstream reaches of streams in several upland areas of northern Florida that possess relatively pristine and exemplary ravine ecosystems. The objectives of the survey were to inventory the species of Trichoptera and Plecoptera occurring at the 4 study areas and to characterize species occurrences in terms of geographic distributional patterns, species/habitat associations, and distinctive faunal elements. Survey data presented in this chapter were also used for analyzing Trichoptera community structure (Chapter 3) and characterizing caddisfly and stonefly adult seasonality (Chapter 4).

Previous Work

Apalachicola Bluffs and Ravines

Of the areas studied, the Torreya ravines historically received the most attention from early 20th century entomologists, probably a result of the region's botanical peculiarities. Well known entomologists who studied the Torreya area's insect biodiversity included Lewis Berner (Ephemeroptera), C.F. Byers and M.J. Westfall (Odonata), T.H. Hubbell (Orthoptera), J. Speed Rodgers (Diptera:Tipulidae), and F.K.

Young (aquatic beetles). As indicated, Trichoptera and Plecoptera were not of primary interest to early entomologists visiting the Torreya ravines; therefore, little effort was devoted to their study. Results of early work on the insect groups that were studied and other aquatic fauna such as crayfish and amphibians indicated that, like the flora, the aquatic fauna shows close biogeographic affinities with the Appalachian highlands and includes narrow-range endemics (Hubbell et al., 1956; Neill, 1957). Entomologists have continued to be drawn to the Torreya area, and through their concerted collecting efforts, much has been learned concerning the area's insect fauna, terrestrial insects in particular. Aside from the Apalachicola ravines, other ravine habitats in northern Florida have not been extensively sampled by entomologists—as a result, their insect fauna remains relatively unknown.

Regional Surveys of Trichoptera and Plecoptera

In order to characterize the species composition and biodiversity of Trichoptera and Plecoptera in ravine assemblages adequately, it was necessary to examine survey results in the context of the component species' geographic ranges and occurrences in other habitats. Without this broader knowledge, the fauna of a particular habitat assemblage cannot be described in terms of its distinctiveness, and characterization must be left to simply presenting checklists of species occurrences. Previous and ongoing studies of caddisfly and stonefly biodiversity within northern Florida and neighboring states have provided much of the needed information to allow placing the survey findings into a larger context. Comprehensive inventories of the Trichoptera fauna of Alabama (Harris et al., 1991) and Mississippi and southeastern Louisiana (Harris et al., 1982; Holzenthal et al., 1982; Lago et al., 1982) were particularly useful in this regard.

The first statewide survey for stoneflies in Florida was a checklist of 17 species presented in Berner (1948). The records presented in Berner's checklist were based on specimens he collected during his expeditions in the 1930's to collect mayflies. Among the stonefly records presented by Berner are collections from the Apalachicola ravines region, including Torreya State Park, Sweetwater Creek and Little Sweetwater Creek. Subsequent studies of the stonefly fauna of Florida have focused mainly on larger creeks and rivers—particularly within the Blackwater, Ochlockonee, and Suwannee river basins—not ravine headwaters. Recent publications that summarized the stonefly fauna of Florida include the papers of Stark and Gaufin (1979), Pescador et al. (2000), and Rasmussen et al. (2003); of these, the last two incorporated stonefly collection data from this study.

Through the work of various Trichopterists, the caddisfly fauna of Florida, as with Plecoptera, is fairly well known. Statewide survey-accounts were provided by Blickle (1962) for Hydroptilidae and by Gordon (1984) for non-hydroptilid caddisflies. Pescador et al. (1995) provided larval keys and an updated species-checklist with distributional data, including preliminary data from this study, on caddisflies found within the Apalachicola ravines and FAMU Farm ravine. Light trapping I have conducted in recent years at various waterbodies (besides ravine streams) in central and northern Florida and southern Georgia was complementary to this study, and these data were used to compare ravine-assemblage species composition with those of other aquatic habitats.

Of the study areas included in this survey, the Eglin area previously was sampled the most extensively for caddisflies. Adult caddisflies were collected from several streams on the eastern side of Eglin Air Force Base by J.F. Scheiring. The results reported in Harris

et al. (1982) included a number of species new to science, several of which were subsequently described in Lago and Harris (1983; 1987) and Bueno-Soria (1981). Of the new species found on Eglin, most are narrow-range endemics—either confined entirely to Eglin, or occupying somewhat larger ranges that extend into other parts of the western panhandle and adjacent coastal Alabama and Mississippi. The stream reaches sampled by Scheiring did not include steephead or upper ravine-reaches. One-time light trapping by B.A. Armitage and M.K. Ward along several streams (downstream reaches) on the western side of Eglin resulted in the discovery of additional new species of microcaddisflies, subsequently described in Harris and Armitage (1987) and Harris (1991).

Materials and Methods

Specimen collecting. Caddisfly and stonefly adults and aquatic stages from the 29 stations were sampled using a variety of qualitative collecting methods. Because less than 50% of the caddisfly and stonefly species occurring in Florida can be identified to species in the larval stage, collection methods targeting adults were emphasized for obtaining species-level data. For each sampling date (Table 2-1), adults, and usually aquatic stages, were collected. Most samples were collected in the spring when most species are present as adults. However, at stations repeatedly sampled, summer and fall samples were also obtained so that species emerging as adults later in the year would not be missed in the survey. Aquatic forms were collected by aquatic dipnet from various benthic microhabitats including rootmats, aquatic macrophytes, leaf packs, snags, and mineral substrates. Benthic sampling consisted of taking several dipnet sweeps from representative benthic microhabitats over a 50-m stream reach. Net samples were put in

white sorting pans, and specimens were field-picked, placed in 80% ethyl alcohol, and returned to the laboratory for identification and curation. Adult stoneflies and caddisflies were collected primarily by light trapping, but sweep netting and a beating sheet were also occasionally employed to supplement light-trap collections and to provide a means of collecting stonefly and caddisfly species not readily drawn to light. The beating sheet was most useful when temperatures were low and insects were not able to escape by flying away. Sweep netting was done during warmer times of year to capture both insects seen flying and to capture individuals resting on riparian vegetation. Light trapping provided the most productive means for capturing adults of most caddisflies species, as well as many stonefly species. Light traps each consisted of a 15-watt UV-blacklight (BioQuip® Item No. 2805) placed over a white pan (30 cm x 25 cm) containing 80% ethyl alcohol. The collecting lights were powered by lightweight 12-volt, sealed rechargeable-batteries (Yuasa NP7-12). Traps were placed near the water's edge and deployed for 1.5-3 hrs beginning at dusk. Typically, 2-5 traps were run on the same night at different stations within a study area. After trapping, the contents of the pans were poured into 0.5-gallon plastic containers and returned to the laboratory for processing. A total of 116 light-trap collections were made.

Specimen identification. Samples were sorted and specimens identified with the aid of a stereomicroscope (Olympus SZH). Processing of the light-trap material often required extensive sorting, and for samples with high numbers of non-target insects such as moths, dipterans, beetles, etc., it was first necessary to separate them from the sample. For most caddisfly and many stonefly species, adult males were primarily used for making species determinations. Because many species were represented by 1 or only-a-

few individuals, samples were not sub-sampled. However, in instances of species being represented by several hundred or more individuals in a light-trap collection, counts were abbreviated due to time constraints. Specimen identifications were to the lowest possible taxonomic level, and, except for some hydroptilid collections, the number of specimens for each species record was tallied. Immature forms and females for many genera could not be identified to species-level and were not included in the analyses. Adult identifications usually required examination of genitalic structures. An extensive body of taxonomic literature was consulted, and collections housed at FAMU served as reference material. Specimens of various taxa were sent to taxonomic specialists for identifications or verifications. Dr. Steven Harris identified all the microcaddisfly (Hydroptilidae) collections; Dr. Paul Lago identified a large number of hydropsychid and polycentropodid specimens; Dr. James Glover verified identifications of *Triaenodes* (Leptoceridae) species. Stonefly specialists that were consulted included Dr. Bill Stark, Dr. Stanley Szczytko, and Dr. Richard Baumann. Synoptic voucher collections will be deposited in the following locations: Florida A&M University Aquatic Insect Collection, Clemson University Arthropod Collection, and in the personal collection of the author. Descriptions of new species and deposition of type material was, or will be, detailed in separate papers.

Data analysis. Specimen collection data from the survey were entered into a relational database (Paradox 9.0) so that specimen data could be easily retrieved and queried. For each species, specimen counts from collections at each sampling station were summed and abundance data were entered into spreadsheet matrices; species richness and abundance values were determined for the different stations and study areas.

Results and Discussion

The survey of ravines in northern Florida for Trichoptera and Plecoptera species diversity revealed a diverse and interesting fauna. A summary of the number of species and specimens identified from each station is presented in Table 2-1. Overall, more than 16,500 specimens were identified to species, and the 138 species of Trichoptera and the 23 species of Plecoptera identified represent approximately 70% and 55%, respectively, of the total known faunas in Florida. The high species richness reflects the wide array of high-quality habitats found within ravine drainage networks that span much of biota-rich northern Florida.

Table 2-1. Summary of survey results (See Chapter 1 for explanation of station coding).

			Trichoptera		Plecoptera	
Station Code	Samples (n)	Sampling Dates	Species (n)	Specimens Identified (n)	Species (n)	Specimens Identified (n)
E1	6	21.v.98; 27.x.98; 10.iii.98; 8.iv.99; 16.vi.99; 10.iv.01	56	912	4	8
E2	6	28.x.98; 10.iii.99; 8.iv.99; 16.vi.99; 2.iii.00; 11.iv.01	41	807	1	6
E3	6	21.v.98; 27.x.98; 10.iii.99; 8.iv.99; 16.vi.99; 10.iv.01	42	454	2	9
E4	7	19.iii.98; 21.v.98; 27.x.98; 10.iii.99; 8.iv.99; 2.iii.00; 11.iv.01	53	866	7	45
E5	3	27.x.98; 7.iv.99; 16.vi.99	19	409	3	12
E6	3	27.x.98; 7.iv.99; 15.vi.99	37	1038	4	7
E7	4	21.v.98; 28.x.98; 7.iv.99; 15.vi.99	56	1219	4	12
E8	1	13.xi.97	13	92	2	2
E9	6	13.xi.97; 21.v.98; 10.iii.99; 7.iv.99; 15.vi.99; 1.xi.99	50	1680	4	9
E10	1	19.iii.98	16	100	0	0
E11	1	19.iii.98	16	121	2	7
E12	1	19.iii.98	16	124	1	1
A1	2	18.iv.95; 7.vi.99	27	375	9	46
A2	4	18.iv.95; 20.xi.98; 1.iv.99; 7.vi.99	38	343	7	75
A3	4	9.iv.98; 20.xi.98; 1.iv.99; 8.vi.99	20	126	3	3
A4	4	9.iv.98; 20.xi.98; 1.iv.99; 8.vi.99	25	277	3	6
A5	2	1.iv.99; 8.vi.99	14	38	5	26
A6	7	19.v.94; 18.iv.95; 24.vi.96; 9.iv.98; 20.xi.98; 1.iv.99; 7.vi.99	44	965	7	34
A7	6	19.v.94; 7.xii.94; 22.iii.95; 30.viii.95; 26.x.95; 24.vi.96	54	697	3	18
A8	2	1.iv.99; 8.vi.99	10	84	2	3
A9	5	7.xii.94; 22.iii.95; 30.viii.95; 26.x.95; 24.vi.96	36	298	7	34

Table 2-1. Continued.

Station Code	Samples (n)	Sampling Dates	Trichoptera Species (n)	Trichoptera Specimens Identified (n)	Plecoptera Species (n)	Plecoptera Specimens Identified (n)
A10	6	7.iv.94; 19.v.94; 7.xii.94; 22.iii.95; 30.viii.95; 26.x.95	55	902	2	17
A11	5	19.v.94; 22.iii.95; 30.viii.95; 26.x.95; 24.vi.96	42	378	6	14
A12	3	7.xii.94; 22.iii.95; 26.x.95	17	282	1	4
F1	5	19.iv.94; 17.v.94; 30.iii.95; 14.ix.95; 11.xi.99	37	690	4	47
F2	5	6.v.93; 6.x.93; 17.v.94; 30.iii.95; 14.ix.95	33	270	2	2
F3	1	14.ix.95	17	34	0	0
G1	5	1.v.98; 27.vi.98; 3.x.98; 6.iii.99; 5.vi.99	28	979	2	209
G2	5	1.v.98; 27.vi.98; 3.x.98; 6.iii.99; 5.vi.99	28	1198	2	103

The following sections give an accounting of species occurrence within the study areas, and notes are included on species geographic distribution and habitat associations; particular attention is paid to faunal elements that are unique to, or characteristic of, the stream habitats sampled. Species conservation status according to the Florida Committee on Rare and Endangered Plants and Animals (FCREPA) is identified, and among the recently discovered species, recommendations are made concerning species that should be considered as candidates for future listing.

Faunal Elements of Special Interest

Among the stonefly and caddisfly species recorded in the survey, I recognize approximately 50 species of special interest (Table 2-2) that represent faunal elements distinctive of the habitats and geographic areas where they occur. Collection records for the majority of these species suggest that the ravines surveyed contain habitats vital for supporting local populations. These species of special interest exemplify the unique biota found in ravine ecosystems, and their occurrences attest to the importance of ravine habitats in supporting a distinct and diverse fauna. Species were designated as species of special interest if they fit into one or more of the following categories: ravine crenobiont, narrow-range endemic, disjunct, listed by FCREPA as Rare or Threatened. The

terminology "ravine crenobiont", "narrow-range endemic", and "disjunct" should be defined to prevent misunderstanding. A species restricted to ravine-head springruns is referred to as a "ravine crenobiont" because of its close ecological association and confinement to ravine crenal habitats. A "narrow-range endemic" for this study is defined as a species having its entire geographic range within the lower (coastal) areas of the Southeastern Coastal Plain. A species referred to as "disjunct" has populations within the study areas that are separated by considerable distances from the species' main geographic range, typically with few, if any, intervening populations on the Southeastern Coastal Plain.

Table 2-2. Species of special interest: ravine crenobionts, narrow-range endemics, disjuncts, and species listed by the Florida Committee on Rare and Endangered Plants and Animals (FCREPA) as Rare (R), Threatened (T), or of Undetermined Status (U).

Species[a]	Study Area Occurrence	Ravine Crenobiont	Narrowly endemic	Disjunct	FCREPA Status[b]
TRICHOPTERA					
Hydropsychidae					
Cheumatopsyche gordonae	E		X		T
Cheumatopsyche petersi	E		X		R
Diplectrona modesta	E, A, F	X			
Diplectrona sp. A	G	X	X		
Philopotamidae					
Chimarra falculata	E, A		X		
Polycentropodidae					
Cernotina truncona	G				R
Nyctiophylax morsei	E		X		R
Polycentropus clinei	G			X	
Polycentropus floridensis	E		X		T
Hydroptilidae					
Hydroptila apalachicola	A		X		
Hydroptila bribriae	E		X		
Hydroptila circangula	E		X		
Hydroptila eglinensis	E		X		
Hydroptila hamiltoni	E		X		
Hydroptila latosa	E, G		X		R
Hydroptila lloganae	E				R
Hydroptila molsonae	E		X		R
Hydroptila okaloosa	E		X		
Hydroptila parastrepha	E		X		
Hydroptila sarahae	E		X		
Neotrichia armitagei	E, G		X		
Ochrotrichia apalachicola	E, A		X		
Orthotrichia baldufi	A, F			X	

Table 2-2. Continued.

Species[a]	Study Area Occurrence	Ravine Crenobiont	Narrowly endemic	Disjunct	FCREPA Status[b]
Orthotrichia curta	G				R
Oxyethira chrysocara	G		X		
Oxyethira elerobi	E				R
Oxyethira florida	E, G		X		T
Oxyethira grisea	A			X	
Oxyethira kelleyi	E		X		T
Oxyethira setosa	A				R
Beraeidae					
Beraea n. sp.	E	X	X		
Brachycentridae					
Micrasema n. sp.	E		X		
Calamoceratidae					
Heteroplectron americanum	E, A, F	X		X	
Lepidostomatidae					
Lepidostoma griseum	A			X	
Lepidostoma latipenne	A			X	
Lepidostoma serratum	E, F	X		X	
Leptoceridae					
Ceraclea diluta	E			X	
Nectopsyche paludicola	E		X		U
Oecetis daytona	E, G				R
Triaenodes helo	A		X		R
Triaenodes taenia	A, F	X		X	
Molannidae					
Molanna blenda	E, A, F	X		X	
Odontoceridae					
Psilotreta frontalis	E, A, F	X		X	
Sericostomatidae					
Agarodes logani	F	X	X		
Agarodes ziczac	E		X		T
PLECOPTERA					
Leuctridae					
Leuctra cottaquilla	E		X		
Leuctra triloba	A, F	X		X	
Perlidae					
Acroneuria lycorias	E, A, F			X	
Eccoptura xanthenes	A, F	X		X	
Perlesta sp. A	E		?		
Perlesta sp. B	E		?		
Pteronarcyidae					
Pteronarcys dorsata	E, A			X	

[a] Higher classification and author names are omitted (see Tables 2-3 to 2-6).
[b] Conservation status taken from Deyrup and Franz (1994)

Eleven species of ravine crenobionts were recorded in the survey: 9 caddisfly species and 2 stonefly species. Of these, 3 caddisfly species (*Diplectrona* sp. A, *Beraea* n. sp., *Agarodes logani*) appear to be narrow-range endemics. The other ravine crenobionts are

species that typically occur in small, cool streams of more northern latitudes. Other species were inventoried that are not restricted to upper reaches of ravine streams, but are narrowly endemic or have disjunct populations occurring within the stream systems sampled. More than 25 narrowly-endemic species were recorded from the streams surveyed; the majority (15 species) belong to the Trichoptera family Hydroptilidae. All study areas contained narrow-range endemics, but the Eglin study area showed by far the highest degree of endemism. Of the 92 species of caddisflies inventoried at the Eglin stations, 22 species (24%) are narrow-range endemics. By all indications, Eglin's spring-fed streams, due to their high-quality habitats and physical isolation, are a major center of caddisfly endemism within the Southeastern Coastal Plain. As discussed in the following survey accounts, some narrow-range endemics appear to be restricted within the particular study area, or possibly a single stream system, while other species occur across somewhat larger areas. Differences in relative abundance were significant, and these differences give some indication as to which species are most important to ecosystem functioning. Many of the endemics listed appear to be not as common or as abundant from outside the study area, and it seems probable that speciation occurred locally (autochthonous endemics) and dispersal to a wider geographic area is limited due to environmental factors. Because of restricted distributions of these species, they are particularly vulnerable to extinction. Sixteen caddisfly species reported in the survey are considered by the Florida Committee on Rare and Endangered Plants to be Rare or Threatened (Deyrup & Franz, 1994). There were a number of species collected that are disjunct from their main geographic ranges. Many of these species likely are unable to tolerate high temperature extremes, and thus are restricted in Florida to thermally-

buffered steephead and clayhill ravine streams. The majority of disjuncts occur in the central panhandle region and likely dispersed to the region from the southern Appalachian highlands via Apalachicola-Flint-Chattahoochee watershed connections.

Survey Account of Trichoptera

Overall, 138 Trichoptera species representing 37 genera and 17 families were identified from among the 116 samples taken at the 29 collecting stations. A total of 15,758 specimens were identified to species. The family Hydroptilidae contained the most species (44) inventoried, followed by Leptoceridae (32), Hydropsychidae (17), Polycentropodidae (13), Philopotamidae (5) Sericostomatidae (4), Dipseudopsidae (3), Brachycentridae (3), Lepidostomatidae (3), Molannidae (3), Phryganeidae (3), Calamoceratidae (2), Limnephilidae (2), Psychomyiidae (1), Rhyacophilidae (1), Odontoceridae (1), Beraeidae (1). Species richness for the 4 study areas was as follows: Eglin (92 species), Apalachicola (89 species), FAMU Farm (49 species), and Gold Head (35 species). Caddisfly faunal composition differed significantly among study areas, and many species were recorded from only a single study area. Collections from each study area contained the following number of species recorded solely within that particular study area: Eglin (31 species), Apalachicola (23 species), FAMU Farm (4 species), and Gold Head (6 species). The Trichoptera species inventory, presented in Tables 2-3 to 2-5, is discussed below. Family subheadings and species are arranged alphabetically under each of the 3 widely recognized Trichoptera suborders (Annulipalpia, Spicipalpia, Integripalpia).

Table 2-3. Survey Summary (Trichoptera:Annulipalpia).

Species	Coll. (n)	Specimens (n)	Study Area (% of Total Specimens) [Collection Station Number]
Dipseudopsidae			
Phylocentropus carolinus Carpenter	22	49	**E**(14)[9]; **A**(80)[2,5-7,10]; **F**(6)[1,2]
Phylocentropus lucidus (Hagen)	21	54	**A**(39)[2,3,7,9-12]; **F**(61)[1-3]
Phylocentropus placidus (Banks)	9	11	**E**(27)[1,2]; **A**(73)[2,6,9,12]
Hydropsychidae			
Cheumatopsyche burksi Ross	2	2	**E**(50)[2]; **F**(50)[2]
Cheumatopsyche campyla Ross	7	49	**A**(100)[1,2,4,6,10,12]
Cheumatopsyche edista Gordon	15	39	**E**(8)[2,9]; **A**(84)[1-4,6,7,10,11]; **F**(8)[1,2]
Cheumatopsyche gordonae Lago & Harris	21	231	**E**(100)[1-8,10,11]
Cheumatopsyche petersi Ross et al.	16	79	**E**(100)[1,2,4-7,9-12]
Cheumatopsyche pettiti (Banks)	25	64	**E**(8)[2,3,7]; **A**(41)[2-4, 6,7,9-12]; **F**(51)[1,2]
Cheumatopsyche pinaca Ross	30	1053	**A**(24)[1,2,4,6-11]; **F**(1)[1,2]; **G**(75)[1,2]
Cheumatopsyche virginica Denning	19	36	**E**(92)[1-4,6,7,9,10,12]; **A**(8)[10,11]
Diplectrona modesta Banks	58	1150	**E**(57)[1-8]; **A**(26)[3,7-12]; **F**(17)[1,2]
Diplectrona sp. A	3	19	**G**(100)[1]
Hydropsyche betteni Ross	2	3	**F**(100)[2,3]
Hydropsyche decalda Ross	1	2	**G**(100)[1]
Hydropsyche elissoma Ross	37	212	**E**(72)[1-7,9-12]; **A**(27)[2,6,7,9-11]; **F**(1)[1,3]
Hydropsyche incommoda Hagen	35	1003	**E**(0.2)[1,6]; **A**(99.7)[1,2,4-12]; **F**(0.1)[1]
Hydropsyche rossi Flint et al.	23	161	**E**(0.6)[7]; **A**(99.4)[1,2,4,6,7,10-12]
Macrostemum carolina (Banks)	10	107	**E**(100)[1-7,9]
Potamyia flava (Hagen)	8	32	**A**(100)[4,6,10,12]
Philopotamidae			
Chimarra aterrima (Hagen)	27	152	**E**(24)[1,3,7,9]; **A**(31)[7,10-12]; **F**(4)[1,2]; **G**(41)[1,2]
Chimarra falculata Lago & Harris	47	472	**E**(89)[1-11]; **A**(11)[7-11]
Chimarra florida Ross	26	173	**E**(31)[1-4,6,9,12]; **A**(9)[5,7,9,10,12]; **G**(60)[1,2]
Chimarra moselyi Denning	9	56	**E**(82)[1,2,6,7,9]; **A**(18)[1,2,6,12]
Chimarra obscura (Walker)	5	7	**A**(43)[1,9,11]; **F**(57)[1]
Polycentropodidae			
Cernotina calcea Ross	1	1	**E**(100)[9]
Cernotina spicata Ross	1	1	**A**(100)[7]
Cernotina truncona Ross	1	1	**G**(100)[1]
Cyrnellus fraternus (Banks)	1	1	**A**(100)[1]
Neureclipsis crepuscularis (Walker)	10	62	**E**(3)[1,3]; **A**(97)[1,6,9-12]
Neureclipsis melco Ross	13	31	**E**(100)[1,2,4,6,7,9,11]
Nyctiophylax affinis (Banks)	1	3	**F**(100)[2]
Nyctiophylax morsei Lago & Harris	10	34	**E**(100)[1-4,6,7,9]
Nyctiophylax serratus Lago & Harris	6	8	**E**(38)[1,7,9]; **A**(12)[6]; **G**(50)[2]
Polycentropus blicklei Ross & Yamamoto	12	27	**A**(11)[3,6,9]; **F**(7)[1,2]; **G**(82)[1,2]
Polycentropus cinereus Hagen	23	64	**E**(48)[1-7,10]; **A**(38)[3,6,7,10,11]; **F**(8)[2,3]; **G**(6)[1,2]
Polycentropus clinei (Milne)	1	1	**G**(100)[2]
Polycentropus floridensis Lago & Harris	6	24	**E**(100)[1,2,7,9]
Psychomyiidae			
Lype diversa (Banks)	71	593	**E**(86)[1-12]; **A**(13)[2,3,5-12]; **F**(1)[1,2]

Table 2-4. Survey Summary (Trichoptera:Spicipalpia).

Species	Coll. (n)	Specimens (n)[a]	Study Area (% of Total Collections) [Collection Station Number]
Hydroptilidae			
Hydroptila apalachicola Harris et al.	1	3	**A**(100)[10]
Hydroptila berneri Ross	1	1	**A**(100)[10]
Hydroptila bribriae Harris	7	30	**E**(100)[1,3,4,11]
Hydroptila circangula Harris	3	3	**E**(100)[7,9,12]
Hydroptila disgalera Holzenthal & Kelley	5	8	**E**(80)[4,9,11]; **A**(20)[6]
Hydroptila eglinensis Harris	9	80	**E**(100)[1-5,7]
Hydroptila hamiltoni Harris	4	25	**E**(100)[1,4,7]
Hydroptila latosa Ross	15	25+	**E**(67)[1,3,4,8,9,11,12]; **G**(33)[1,2]
Hydroptila lloganae Blickle	2	2	**E**(100)[1,4]
Hydroptila molsonae Blickle	1	1+	**E**(100)[7]
Hydroptila novicula Blickle & Morse	1	1	**F**(100)[3]
Hydroptila okaloosa Harris	3	8	**E**(100)[1,7]
Hydroptila parastrepha Kelley & Harris	3	3	**E**(100)[4,10,11]
Hydroptila quinola Ross	22	88+	**E**(27)[1,3,4,7-9]; **A**(68)[1-4,6,7,9-11]; **F**(5)[1]
Hydroptila remita Blickle & Morse	14	32+	**E**(43)[4,6,7,10,12]; **A**(57)[7,9-11]
Hydroptila sarahae Harris	9	30	**E**(100)[1,2,4,6,7,9]
Hydroptila waubesiana Betten	15	135+	**E**(80)[2-4,6,7,9-11]; **F**(13)[1]; **G**(7)[2]
Mayatrichia ayama Mosely	13	13+	**E**(46)[4,6,7,9]; **A**(8)[7]; **F**(8)[3]; **G**(38)[1,2]
Neotrichia armitagei Harris	8	8+	**E**(25)[1,9]; **G**(75)[1,2]
Neotrichia minutisimella (Chambers)	1	7	**A**(100)[7]
Neotrichia vibrans Ross	1	1	**A**(100)[9]
Ochrotrichia apalachicola Harris et al.	2	6	**E**(50)[3]; **A**(50)[7]
Ochrotrichia confusa (Morton)	1	1	**A**(100)[12]
Orthotrichia aegerfasciella (Chambers)	9	11+	**E**(33)[1,7]; **A**(33)[7,9]; **F**(23)[1,3]; **G**(11)[2]
Orthotrichia baldufi Kingsolver & Ross	2	4	**A**(50)[7]; **F**(50)[3]
Orthotrichia cristata Morton	3	36	**E**(34)[1]; **A**(33)[2]; **F**(33)[3]
Orthotrichia curta Kingsolver & Ross	2	2+	**G**(100)[1,2]
Oxyethira abacatia Denning	11	14+	**E**(37)[1,3,7]; **A**(27)[7,10]; **F**(9)[1]; **G**(27)[1,2]
Oxyethira chrysocara Harris	1	1	**G**(100)[2]
Oxyethira elerobi (Blickle)	2	4+	**E**(100)[4,9]
Oxyethira florida Denning	2	2+	**E**(50)[1]; **G**(50)[1]
Oxyethira glasa (Ross)	8	9+	**E**(25)[1,6]; **A**(25)[10]; **G**(50)[1,2]
Oxyethira grisea Betten	1	1	**A**(100)[7]
Oxyethira janella Denning	23	155+	**E**(26)[1,3,4,7,9]; **A**(44)[2,4,6,7,10,11]; **F**(17)[1-3]; **G**(13)[1,2]
Oxyethira kelleyi Harris	13	45+	**E**(100)[1,3,4,7-12]
Oxyethira lumosa Ross	16	95	**E**(37)[1,3,4,7,9]; **A**(44)[3,7,10,11]; **G**(19)[1,2]
Oxyethira maya Denning	14	27+	**E**(36)[1,3,7,9]; **A**(64)[1,2,6,7,9-11]
Oxyethira novasota Ross	17	59+	**E**(6)[4]; **A**(76)[2,6,7,9-11]; **F**(18)[1,2]
Oxyethira pallida (Banks)	4	9	**A**(75)[10,11]; **F**(25)[3]
Oxyethira pescadori Harris & Keth	7	24	**E**(86)[1,3,4]; **G**(14)[[1]
Oxyethira savanniensis Kelley & Harris	6	28+	**E**(67)[1,4,6,9]; **G**(33)[2]
Oxyethira setosa Denning	1	1	**A**(100)[7]
Oxyethira verna Ross	1	1	**A**(100)[7]
Oxyethira zeronia Ross	10	59+	**E**(80)[1,3,4,6,7,9,10]; **A**(20)[1,2]
Rhyacophilidae			
Rhyacophila carolina Banks[b]	34	91	**E**(64)[1-4,7]; **A**(30)[3,4,7,9-12]; **F**(6)[1,2]

[a] + indicates that specimen counts were not made for 1 or more collections.

[b] Survey area % abundances based on total individuals.

Table 2-5. Survey Summary (Trichoptera:Integripalpia).

Species	Coll. (n)	Specimens (n)	Study Area (% of Total Specimens) [Collection Station Number]
Beraeidae			
Beraea n. sp.	3	4	**E**(100)[1]
Brachycentridae			
Brachycentrus chelatus Ross	21	83	**E**(98)[2-4,6-12]; **A**(2)[10]
Micrasema n. sp.	27	1119	**E**(100)[1-12]
Micrasema wataga Ross	9	33	**A**(9)[10]; **G**(91)[1,2]
Calamoceratidae			
Anisocentropus pyraloides (Walker)	49	540	**E**(47)[1-9,11,12]; **A**(41)[1-3, 5-11]; **F**(12)[1,2]
Heteroplectron americanum (Walker)	19	123	**E**(61)[1-5,7]; **A**(37)[5,6,8,9,11]; **F**(2)[1,2]
Lepidostomatidae			
Lepidostoma griseum (Banks)	4	13	**A**(100)[7,9-11]
Lepidostoma latipenne (Banks)	9	13	**A**(100)[3,5,7,9,11]
Lepidostoma serratum Flint & Wiggins	7	31	**E**(29)[1,5]; **F**(71)[1,2]
Leptoceridae			
Ceraclea cancellata (Betten)	8	23	**A**(100)[2,4,6,7,11]
Ceraclea diluta (Hagen)	8	35	**E**(100)[2,4,6,7,9]
Ceraclea flava (Banks)	2	2	**A**(100)[1,6]
Ceraclea maculata (Banks)	19	43	**E**(33)[1,4,7,9,10,12]; **A**(67)[1,2,4,6,10,11]
Ceraclea nepha (Ross)	5	17	**A**(100)[2,4,6]
Ceraclea ophioderus (Ross)	1	1	**A**(100)[4]
Ceraclea protonepha Morse & Ross	10	133	**E**(1)[6]; **A**(99)[1,2,4-6,10]
Ceraclea resurgens (Walker)	4	13	**E**(100)[2,4,12]
Ceraclea tarsipunctata (Vorhies)	9	333	**A**(100)[1,2,4,6,10]
Ceraclea transversa (Hagen)	11	51	**A**(98)[2-6]; **F**(2)[1]
Leptocerus americanus (Banks)	5	22	**A**(55)[1,6]; **F**(45)[1,2]
Nectopsyche candida (Hagen)	1	1	**E**(100)[4]
Nectopsyche exquisita (Walker)	15	79	**E**(18)[4,7]; **A**(82)[1,2,6,7,9,10]
Nectopsyche paludicola Harris	40	832	**E**(100)[1-12]
Nectopsyche pavida (Hagen)	19	593	**E**(7)[2,7,9]; **A**(2)[6,10]; **G**(91)[1,2]
Oecetis cinerascens (Hagen)	10	20	**E**(15)[1,7,9]; **A**(80)[1,2,6,11]; **F**(5)[3]
Oecetis daytona Ross	3	3	**E**(67)[6,7]; **G**(33)[1]
Oecetis ditissa Ross	16	24	**E**(21)[3,4,7]; **A**(37)[1,7,9,10]; **F**(42)[1-3]
Oecetis georgia Ross	27	90	**E**(19)[1,3,4,7,9,11]; **A**(17)[2,4,7,9-11]; **F**(3)[1,2]; **G**(61)[1,2]
Oecetis inconspicua Complex	71	875	**E**(69)[1-9]; **A**(25)[1-11]; **F**(5)[1-3]; **G**(1)[1,2]
Oecetis nocturna Ross	9	10	**E**(10)[3]; **A**(80)[1,2,4,7,9,10]; **F**(10)[2]
Oecetis osteni Milne	15	18	**E**(22)[3,6,7,9]; **A**(61)[2,6,7,9,11]; **F**(11)[1,2]; **G**(6)[2]
Oecetis persimilis (Banks)	17	47	**E**(9)[1,4,6,9]; **A**(91)[1,2,4,6,7,11,12]
Oecetis sphyra Ross	26	572	**E**(62)[2,4-7,9]; **A**(35)[1,2,4-7,9-11]; **F**(3)[1,2,3]
Triaenodes aba Milne	1	1	**A**(100)[10]
Triaenodes helo Milne	2	4	**A**(100)[7,10]
Triaenodes ignitus (Walker)	50	319	**E**(6)[1,3,4,6,7,9]; **A**(45)[1-7,9-11]; **F**(4)[1-3]; **G**(45)[1,2]
Triaenodes n. sp.	6	6	**E**(100)[2-4,9]
Triaenodes ochraceus (Betten & Mosely)	1	1	**A**(100)[10]
Triaenodes perna Ross	5	12	**E**(100)[2,6,7,9]
Triaenodes taenia Ross	4	7	**A**(14)[3]; **F**(86)[1,2]
Triaenodes tardus Milne	4	6	**A**(100)[1,2,6]

Table 2-5. Continued.

Species	Coll. (n)	Specimens (n)	Study Area (% of Total Specimens) [Collection Station Number]
Limnephilidae			
Pycnopsyche antica (Walker)	25	287	**E**(45)[2-4,6-9]; **A**(28)[2,3,6,7,9-11]; **F**(1)[1]; **G**(26)[1,2]
Pycnopsyche indiana (Ross)	1	1	**E**(100)[2]
Molannidae			
Molanna blenda Sibley	38	184	**E**(69)[1-5,7]; **A**(13)[3,7,9-11]; **F**(18)[1,2]
Molanna tryphena Betten	25	63	**E**(13)[2,4,6]; **A**(54)[5-7,10]; **F**(3)[2,3]; **G**(30)[1,2]
Molanna ulmerina Navás	7	15	**E**(100)[1,2,6]
Odontoceridae			
Psilotreta frontalis Banks	21	510	**E**(4)[2,5]; **A**(17)[3,7-12]; **F**(79)[1,2]
Phryganeidae			
Banksiola concatenata (Walker)	1	1	**E**(100)[2]
Ptilostomis ocellifera (Walker)	2	2	**E**(100)[9]
Ptilostomis postica (Walker)	5	5	**A**(40)[4,7]; **F**(60)[1,2]
Sericostomatidae			
Agarodes crassicornis (Walker)	12	61	**E**(78)[3,7,9,10]; **A**(13)[7,10,11]; **F**(2)[1]; **G**(7)[1]
Agarodes libalis Ross & Scott	15	248	**A**(29)[7,8,10,11]; **G**(71)[1,2]
Agarodes logani Keth & Harris	4	5	**F**(100)[1,2]
Agarodes ziczac Ross & Scott	23	951	**E**(100)[1-7,9,12]

Suborder Annulipalpia (Table 2-3)

Family Dipseudopsidae

Three widespread eastern North American *Phylocentropus* species (*P. carolinus*, *P. lucidus*, *P. placidus*) were recorded in the survey. *Phylocentropus* species were most common within the central panhandle study areas. *Phylocentropus lucidus* showed the most restricted distribution and was collected from only stations within the central panhandle region. Larvae of *P. lucidus* were found in small, sandy seeps. The other 2 species occurred across a wider geographic area and array of habitat types. However, no *Phylocentropus* species were collected from Gold Head Branch even though both *P. carolinus* and *P. placidus* occur in small spring-fed streams of the northern Florida peninsula.

Family Hydropsychidae

A total of 17 species grouped within 5 genera were inventoried. The genus containing the greatest number of species was *Cheumatopsyche* (8), followed by

Hydropsyche (5), *Diplectrona* (2) and *Macrostemum* and *Potamyia* (1 species each). Species composition and abundances at the sampling stations reflected species stream-size preferences, as well as large-scale regional differences in the species geographic ranges.

Genus *Cheumatopsyche*. Differences in *Cheumatopsyche* species composition at the regional and local scales were evident. In the western panhandle region at the Eglin stations, the 2 most abundant species were *Cheumatopsyche gordonae* and *Cheumatopsyche petersi*, both of which have restricted distributions. *Cheumatopsyche gordonae*, widespread and abundant within streams on Eglin Air Force Base, is unknown outside this region. Accordingly, the species was listed by FCREPA as Threatened. *Cheumatopsyche petersi* (listed by FCREPA as Rare) has a somewhat larger range that includes parts of the western Florida panhandle, coastal Alabama, and Mississippi. Results of the Eglin collecting showed that *C. gordonae* occurs most often in the upper- and middle- stream reaches, while *C. petersi* is most abundant in larger streams and rivers such as the Blackwater River. *Cheumatopsyche virginica*, a Coastal Plain species, was also common and widespread on Eglin streams but infrequently collected from the Apalachicola stations. Conversely, *Cheumatopsyche edista*, also a Coastal Plain species, was common from the central panhandle stations but was infrequently collected from the Eglin stations. *Cheumatopsyche campyla* was collected only from the Apalachicola study area, mainly from the larger streams or at stations very near the Apalachicola River, suggesting the river's proximity is an important influence on the occurrence of this species. *Cheumatopsyche pinaca* was taken in high numbers from larger streams of the Apalachicola study area and also at Gold Head Branch, where the highest numbers were

recorded and this was the only *Cheumatopsyche* species collected. *Cheumatopsyche pettiti*, a transcontinental species, collected at most of the central panhandle stations, was less common on Eglin, perhaps due to abundant populations of *C. gordonae* and *C. petersi*.

Genus *Diplectrona*. *Diplectrona modesta* accounted for the highest total hydropsychid abundance (1150 specimens). Within the panhandle study areas, this species was the dominant hydropsychid at steephead and upper ravine-reaches. Larvae occurred abundantly within leaf packs and small debris-dams. Downstream from ravine-head reaches this species became less abundant and was replaced by *Cheumatopsyche* and *Hydropsyche* species. Adults appearing to be *D. modesta* were collected from the steephead at Gold Head Branch, which is east and south of the known range for *D. modesta*. However, larvae of *Diplectrona* collected at the steephead all possessed a head coloration pattern different from typical larvae of *D. modesta*; therefore, this species was designated *Diplectrona* sp. A. The coloration pattern of the head is similar to *Diplectrona rossi*, which is known only from Schoolhouse Springs in Louisiana. However, the larvae of *Diplectrona* sp. A have evenly curved frontoclypeal sutures unlike those of *D. rossi*, which angle sharply near the anterior tentorial pits (Morse & Barr, 1990). Pupal collections of *Diplectrona* sp. A may help to clarify the identity of this potential new species.

Genus *Hydropsyche*. The *Hydropsyche* caddisflies inventoried comprise 5 species, with 3 species (*H. elissoma*, *H. incommoda*, and *H. rossi*) collected in relatively high numbers from widespread panhandle stations, as compared to the scant collections of *H. betteni* and *H. decalda*. *Hydropsyche elissoma* was the dominant *Hydropsyche* species at

the Eglin stations, while the Apalachicola study area supported *H. elissoma*, as well as high numbers of *H. incommoda* and *H. rossi*. *Hydropsyche incommoda* was very abundant in light-trap collections at stations near the Apalachicola River, suggesting that close proximity to the river is an important influence on the abundance of this species, which is known to inhabit large Coastal Plain rivers. At Gold Head Branch, the only *Hydropsyche* identified were 2 males of *H. decalda*. *Hydropsyche betteni* was collected from only the FAMU Farm Stream.

Genus *Macrostemum*. A single species was inventoried, *M. carolina*. The species is widespread in the eastern USA and throughout much of northern Florida, but in this survey was collected solely from Eglin streams, where it was widespread and common in light-trap collections.

Genus *Potamyia*. The single North American species of this genus, *Potamyia flava*, was taken in light-trap collections from several stations located near the Apalachicola River. The species is known to inhabit large rivers, and the adults collected likely moved from the river into nearby tributary reaches.

Family Philopotamidae

Chimarra species were significant components of the caddisfly fauna at most of the stream reaches sampled. All five species known to occur in Florida were collected (*C. aterrima*, *C. falculata*, *C. florida*, *C. moselyi*, *C. obscura*). *Chimarra falculata* was the most abundant with nearly 90% of all specimens collected at stations on Eglin, where this species of restricted distribution appears to have the highest population density. Besides the Florida panhandle, the geographic range of *C. falculata* includes the lower Coastal Plain of Mississippi and Alabama, and parts of southwestern Georgia. *Chimarra florida*

has a similar distribution, but extends its range north and east into parts of the Atlantic Coastal Plain and the Florida peninsula. More than half the *C. florida* collected came from Gold Head Branch Station 2. Of the widespread eastern North America species, *C. aterrima* and *C. obsura*, *C. aterrima* was common and fairly abundant across study areas at various sampling stations, while *C. obscura* was collected in low numbers from only a few central panhandle stations. *Chimarra moselyi* occurred at many of the panhandle stations, but usually in low numbers.

Family Polycentropodidae

Polycentropodidae were represented in the survey by 5 genera and 13 species. Among these are both common and widespread species, as well as 1 disjunct occurrence of a species never collected before in Florida and 3 restricted-range species that were listed by FCREPA as Rare or Threatened. Seven species were each represented by fewer than 10 individuals, and none of the polycentropodids were collected, either as adults or larvae, in high numbers as were representatives from most of the other annulipalpian families.

Genus *Cernotina*. Three species were recorded (*C. calcea*, *C. spicata*, *C. truncona*), each represented by only 1 individual, indicating that *Cernotina* species are minor constituents of the caddisfly fauna of ravine assemblages. *Cernotina truncona* is an uncommon Southeastern Coastal Plain species listed by FCREPA as Rare. This species, collected at Gold Head Branch, is thought to be associated with ponds and lakes and could have entered the ravine from one of the nearby lakes.

Genus *Cyrnellus*. The collection of only a single individual of *Cyrnellus fraternus* indicates that this widespread and abundant river species is an incidental constituent of ravine assemblages.

Genus *Neureclipsis*. The 2 species inventoried (*N. crepuscularis*, *N. melco*) were collected only from Eglin and Apalachicola stations. The widespread and common river species *N. crepuscularis* was collected as 1 or 2 individuals from a variety of upper and lower reach stations, but was collected in greatest abundance at station A12 near the Apalachicola River. Within the Eglin study area, *N. melco*, a Southeastern endemic, was the more common and widespread species.

Genus *Nyctiophylax*. Three *Nyctiophylax* species were inventoried (*N. affinis*, *N. morsei*, and *N. serratus*). Among these 3 species is the widespread North American species (*N. affinis*), a southeastern endemic (*N. serratus*), and *N. morsei*, endemic to small, cool streams of the western Florida panhandle and coastal Alabama. Within this survey, *N. serratus* was the most widespread, occurring across the panhandle stations as well as from Gold Head Branch. *Nyctiopylax morsei* was collected from a majority of Eglin stations and overall was the most abundant *Nyctiophylax* species. *Nyctiophylax morsei*, along with *Polycentropus floridensis*, form a pair of syntopic endemics unique to the spring-fed streams on Eglin.

Genus *Polycentropus*. Four *Polycentropus* species were inventoried (*P. blicklei*, *P. cinereus*, *P. clinei*, *P. floridensis*), and all of them have contrasting distributions. *Polycentropus cinereus*, a transcontinental species, was the most widespread and abundant in the survey. *Polycentropus blicklei* was also widespread, occurring in all study areas except Eglin. It was collected most frequently and abundantly from the Gold

Head Branch springrun. Other collections of *P. blicklei* comprised only single individuals. This species appears to be restricted in Florida to small spring-fed streams. Also from Gold Head Branch, a single male of *Polycentropus clinei* was identified. This species is mainly northeastern in distribution with disjunct populations having also been found within Minnesota and coastal Alabama (Harris et al., 1991). However, because it has been sparsely collected on the Coastal Plain, it is difficult to make firm inferences as to its actual distribution. *Polycentropus floridensis* is endemic to spring-fed streams of the western panhandle and coastal Alabama. It was collected from several different Eglin streams suggesting that the species is widespread within Eglin, but not as common in occurrence as other narrow-range endemics such as *Nyctiophylax morsei*, *Cheumatopsyche gordonae*, *Agarodes ziczac*, and *Nectopsyche paludicola*. Appropriately, *P. floridensis* was listed by FCREPA as Threatened.

Family Psychomyiidae

Lype diversa was common at most panhandle stations. In terms of number of collections (71), it was equaled only by *Oecetis inconspicua* complex. In northern Florida habitats other than small spring-fed streams, it is less common.

Suborder Spicipalpia (Table 2-4)

Family Hydroptilidae

Hydroptilidae, also known as microcaddisflies, were the most speciose (44 species representing 6 genera) family of Trichoptera collected. The genera *Hydroptila* and *Oxyethira* were both represented by 17 species; other genera included: *Orthotrichia* (4 spp.), *Neotrichia* (3 spp.) *Ochrotrichia* (2), and *Mayatrichia* (1 sp.). Among the microcaddisflies collected in this study and sent to Dr. Harris for identification were 10

species new to science that have been subsequently described (*Hydroptila apalachicola*, *H. bribriae*, *H. eglinensis*, *H. hamiltoni*, *H. okaloosa*, *H. sarahae*, *H. sykorai*, *Ochrotrichia apalachicola*, *Oxyethira chrysocara*, *O. pescadori*). Formal descriptions of these species were provided in Harris et al. (1998), Harris (2002), and Harris and Keth (2002). As with Integripalpia and Annulipalpia, species composition of hydroptilids varied greatly among study areas. Narrow-range endemics were most prevalent within the Eglin study area. Eglin's cool, clear springruns with abundant vascular plants and macroalgae provide habitat and food resources that sustain a diverse and unique assemblage of microcaddisflies. Several of these endemic species are very similar to more widely occurring Southeastern species (Harris, 2002), and it is likely to a large degree that the origin of this unique fauna is due to speciation of isolated relict populations.

Genus *Hydroptila*. The survey led to the discovery of a number of new species in this large genus. Of the *Hydroptila* specimens sent to Dr. Harris for examination, he discovered 7 species new to science. Five of these (*H. bribriae*, *H. eglinensis*, *H. hamiltoni*, *H. okaloosa*, *H. sarahae*) appear to be endemic to streams on Eglin. The descriptions for these species, provided in Harris (2002), were based in large part on specimens collected as a part of this study. The aforementioned species were all collected from more than one watershed and are probably fairly widespread in the Eglin streams, at least on the western side of the base where the study area was located. These 5 new species, because of their restricted distributions, should be considered for special conservation status. Four additional species (*H. circangula*, *H. lloganae*, *H. molsonae*, *H. parastrepha*) with restricted ranges were also collected from the Eglin study area. Of

these, the distributions of *H. circangula* and *H. parastrepha* encompass parts of the western Florida panhandle and coastal Alabama. *Hydroptila lloganae* (known from TX, LA, FL, and SC) and *H. molsonae*, a Gulf Coastal Plain species, were listed by FCREPA as Rare. Also of note, *Hydroptila latosa*, a Coastal Plain species, was common within the Eglin and Gold Head study areas but was not collected from any central panhandle stations. Endemic to the Apalachicola study area was *Hydroptila apalachicola*. Described in Harris et al. (1998), it is known from only 3 specimens collected at Little Sweetwater Creek (Station A10). It is most similar to *H. recurvata*, a species endemic to the Black Warrior system in Alabama. Overall, the most abundant *Hydroptila* species were 2 very common and widespread species, *H. quinola* and *H. waubesiana*. Other relatively common and widespread *Hydroptila* species inventoried included: *H. berneri*, *H. disgalera*, *H. novicula*, and *H. remita*.

Genus *Mayatrichia*. *Mayatrichia ayama* occurred in all study areas and was most frequently collected at lower reach stations. This species, widespread in North America, is a common river species in Florida.

Genus *Neotrichia*. Three species of *Neotrichia* (*N. armitagei*, *N. minutisimella*, *N. vibrans*) were inventoried. *Neotrichia minutisimella* and *N. vibrans* were collected from single stations within the Apalachicola study area. Both are widely distributed over parts of the eastern and central USA, including most of North and South Florida. *Neotrichia armitagei*, on the other hand, is endemic to streams of northern Florida and adjacent southwestern Georgia. It was described in Harris (1991) from collections made by B.J. Armitage and M.K. Ward from streams on the western-side of Eglin Air Force Base. In

this study, *N. armitagei* was also collected from Eglin, but was most frequently collected from Gold Head Branch where it was abundant at the lower reach (Station G2).

Genus *Ochrotrichia*. Two *Ochrotichia* species were recorded in the survey, *O. apalachicola* and *O. confusa*, both in low numbers. *Ochrotichia confusa* was represented by a single male collected at station A12, a small high-gradient ravine stream located along the eastern bank of the Apalachicola River. *Ochrotrichia apalachicola*, a newly-discovered species, was described in Harris et al. (1998) from a single male collected at Beaver Dam Creek (Station A7). Subsequently, 5 males were identified from Station E3 of the Eglin study area. These are the only known localities for this species, which appears to be endemic to the Florida panhandle. *Ochrotricha okaloosa* was not collected in the study. This rare species, described in Harris and Armitage (1987), is known only from the holotype collected 14 August 1985 on Eglin Air Force Base (Turkey Creek at Base Road 233).

Genus *Orthotrichia*. Within this small genus, a total of 4 species (*O. aegerfasciella*, *O. baldufi*. *O. cristata*, *O. curta*) were inventoried. All study areas were represented by at least 2 species. The widespread and common eastern species, *O. aegerfasciella*, occurred in all study areas and was the most common *Orthotrichia* collected. *Orthotrichia cristata*, also a widespread eastern species, was represented in all panhandle study areas but was less common (3 collections). *Orthotrichia baldufi* occurred only within the central panhandle study areas. This species is northern in distribution, with scattered disjunct populations within the Southeastern USA. *Orthotrichia curta* is a primarily southeastern species and it occurred only within Gold Head study area.

Genus *Oxyethira*. The 17 species of *Oxyethira* identified in this survey were equaled in species richness only by the genus *Hydroptila*. Narrow-range endemic *Oxyethira* species documented in the survey were *O. kelleyi* and *O. chrysocara*. *Oxyethira kelleyi* is widespread and abundant in streams on the western-side of Eglin, but is unknown from outside this area; the species was described in Harris and Armitage (1987) and was listed by FCREPA as Threatened. *Oxyethira chrysocara*, recently described by Harris (2002), is currently known from only the holotype specimen collected at Gold Head Branch (Station G2). Additional collecting in and around the type locality is needed to pinpoint the population center. Three species (*O. grisea*, *O. setosa*, *O. verna*) were recorded only as single individuals from Beaver Dam Creek (Station A7). *Oxyethira grisea* is unknown from any other Florida localities, and its occurrence on the Coastal Plain is disjunct. *Oxyethira setosa*, listed by FCREPA as Rare, was previously known in Florida from one other locality, Rocky Creek on Eglin Air Force Base. Another Threatened species, *O. florida*, was recorded from collections made at 2 steephead stations, Eglin (Station E1) and Gold Head (Station G1). Aside from these collections, the species is known in Florida from only the type locality (Miami) and Temple Terrace near Tampa. *Oxyethira lumosa*, a southeastern species, was collected within the Eglin, Apalachicola, and Gold Head study areas. Dr. Harris closely examined these specimens, and others from northern Florida and Coastal Plain Alabama, and discovered the presence of 2 closely-related species, *Oxyethira lumosa* and a new species, *O. pescadori*, described in Harris and Keth (2002). Subsequently, this new species was also identified from specimens collected by Dr. Manuel Pescador and others in central South Carolina, suggesting that *O. pescadori* may have a similar distribution to *O. lumosa*. *Oxyethira elerobi* was collected only from

the Eglin study area (Stations E4, E9). The species was listed by FCREPA as Rare, but I have found additional populations from small blackwater streams in northern Florida, suggesting that the species is more common than previously thought. Overall, the most widespread and common *Oxyethira* species in all study areas was the southeastern species *O. janella*. Other *Oxyethira* species, not already mentioned, collected at 2 or more study areas included: *O. abacatia*, *O. glasa*, *O. maya*, *O. novasota*, *O. pallida*, *O. savanniensis*, and *O. zeronia*.

Family Rhyacophilidae

Species within the genus *Rhyacophila* are icons of Appalachian stream biota. *Rhyacophila carolina*, unlike other *Rhyacophila* species, is also found in cool, spring-fed streams of the Florida panhandle. The species was widespread within the panhandle study areas and was most abundant at 1^{st}–3^{rd} order springrun reaches.

Suborder Integripalpia (Table 2-5)

Family Beraeidae

A new species within the genus *Beraea* was discovered within the steephead at Station E1. Adult males were light trapped on two occasions, and a female was collected using a beating sheet. The new species will be described in a separate paper. Larvae remain uncollected, but they probably live in mucky seepage areas within the steephead, given that *Beraea* species are noted for their ecological specialization to this type of microhabitat.

Family Brachycentridae

The Brachycentridae surveyed included *Brachycentrus chelatus*, *Micrasema* n. sp., and *M. wataga*. Among these species were an eastern North American species (*M.*

wataga), a southeastern species (*B. chelatus*), and a lower Coastal Plain endemic (*Micrasema* n. sp.). Brachycentrids were most abundant at lower springrun reaches having deeper water and submerged aquatic plants. *Brachycentrus chelatus* was widespread and common on Eglin, but was collected from only one station (A10) outside this study area. *Micrasema* n. sp., described in a dissertation by Chapin (1978), was widespread and abundant at the lower sampling reaches on Eglin. Larvae were found in association with submerged macrophytes and macroalgae (*Batrachospermum*). In contrast, *Micrasema wataga* was not collected at the Eglin stations but did occur within the Apalachicola study area (Station A10) and at Gold Head Branch, where it was most abundant at the downstream sampling reach (Station G2).

Family Calamoceratidae

The calamoceratid species *Anisocentropus pyraloides* and *Heteroplectron americanum* were collected at panhandle stations, primarily from steephead and upper-ravine reaches. Their abundance, large size, and feeding habits as detritivores and shredders of course particulate matter (e.g., leaves), are suggestive of their ecological importance to ecosystem functioning in these habitats. The more common *A. pyraloides* occurred at all such sites; adults were often observed flying during the daytime within the ravines. *Heteroplectron americanum* is more restricted in distribution, and in Florida the species is primarily confined to ravine streams. These isolated Florida populations probably represent relict populations of a distribution less fragmented during cooler climate periods, as during the Pleistocene. Likely due to their warm-water intolerance, neither species has been recorded from peninsular Florida.

Family Lepidostomatidae

Three *Lepidostoma* species were collected (*L. griseum*, *L. latipenne*, *L serratum*). The Florida populations are all southern disjuncts and restricted to cool, well-shaded, spring-fed streams. *Lepidostoma griseum* and *L. latipenne* were collected from only the Apalachicola study area, and both species show Appalachian Highland biogeographic affininites. *Lepidstoma serratum* was collected from ravine heads at the FAMU Farm and on Eglin. The larvae were found on the undersides of chunks of clay-like material that are most prevalent near spring-source headwall areas. Interestingly, male specimens exhibit the same genitalic variation noted in Weaver (1988) for specimens collected from Schoolhouse Springs in Louisiana. The fact that distant populations on the southern Coastal Plain show the same variation and a disjunct distribution pattern suggests that these are relict populations, possibly representing an ancestral form of the species that was forced southward, along with deciduous forest communities, during cooler periods associated with Pleistocene glacial advances.

Family Leptoceridae

Leptoceridae were the most diverse and abundant integripalpian family collected in the survey, with leptocerids accounting for nearly 50% of all integripalpian specimens identified and about 60% of all integripalpian species. Within this family, 32 species representing 5 genera were inventoried. Species richness for each genus was: *Ceraclea* (10), *Oecetis* (9), *Triaenodes* (8), *Nectopsyche* (4), *Leptocerus* (1). The majority of these leptocerids are widespread in eastern North America as well as in Florida. However, there are representatives within *Ceraclea*, *Oecetis*, *Triaenodes*, and *Nectopsyche* that either have disjunct populations in Florida or are narrow-range endemics.

Genus *Ceraclea*. The *Ceraclea* species recorded have, in general, widespread distributions over large parts of eastern North America. They occurred most often and in greatest abundance at the lower-reach stations; at upper-reach ravine stations *Ceraclea* species were quite uncommon. Regional differences in species composition of *Ceraclea* were evident. The Apalachicola study area supported the most species (8), with *C. protonepha*, *C. tarsipunctata*, and *C. transversa* being collected primarily from this region and in the highest overall abundance. *Ceraclea flava*, *C. nepha*, and *C. ophioderus* were collected only at Apalachicola stations but were less common. *Ceraclea maculata* was widespread and common at both Eglin and Apalachicola stations. *Ceraclea diluta* and *C. resurgens* were collected only from Eglin, with *C. diluta* being the more common. Harris et al. (1991) reported both of these species from small streams within coastal Alabama, and from few other Alabama localities. Neither was recorded from streams surveyed on the eastern part of the reservation (Harris et al., 1982).

Genus *Leptocerus*. *Leptocerus americanus* was collected infrequently from a few central panhandle stations. This species is associated with aquatic macrophytes but was not collected as larvae or as adults at downstream stations on Eglin where aquatic macrophytes were abundant. High stream velocities at these stations may account for the absence since *L. americanus* is associated more with lentic habitats.

Genus *Nectopsyche*. *Nectopsyche* species were common and abundant at middle and lower reaches. Within steephead- and upper-ravine reaches, *Nectopsyche* was generally less abundant. Species composition and abundance varied by region. Three (*N. candida*, *N. exqusita*, and *N. pavida*) of the 4 species collected range over much of eastern North America, whereas *N. paludicola* is endemic to the western Florida panhandle and coastal

Alabama. This species was collected from all Eglin stations, often in great abundance. *Nectopsyche exquisita* was the most frequently occurring species from the Apalachicola study area. *Nectopsyche pavida* was collected from the Eglin and Apalachicola study areas, but was most abundant at Gold Head Branch. Collections of this species at the steephead station (G1) comprised several hundred females but only 4 males, whereas the collections downstream at station G2 showed a much more equal sex-ratio, suggesting that females, but not males, were flying upstream. *Nectopsyche candida* was the least common species with only a single specimen being identified.

Genus *Oecetis*. At least nine species of *Oecetis* were collected, and 4-8 congeners were typically found at stations where multiple samples were collected. Most widespread and abundant was the *Oecetis inconspicua* complex (likely comprising 2 or 3 different species). Also widespread and very abundant, particularly in lower reaches, was the southeastern species *Oecetis sphyra*. *Oecetis georgia*, another southeastern species, was collected from all regions but in lower numbers and tended to occur most often in upper reaches. *Oecetis daytona*, endemic to the Southeastern Coastal Plain and listed by FCREPA as Rare, was collected at stations E6, E7, and G1—identified from single males. The other *Oecetis* collected (*O. cinerascens*, *O. ditissa*, *O. nocturna*, *O. osteni*, and *O. persimilis*) are common and widespread eastern species (Floyd, 1995) that were collected at many of the stations.

Genus *Triaenodes*. Eight species of *Triaenodes* were documented in the survey. By far the most widespread and common was *Triaenodes ignitus*—collected more often and in greater total abundance than all other *Triaenodes* species combined. It occurred at the majority of stations and appeared to be ubiquitous in streams of all sizes. Larvae were

most frequently found among submerged rootmats of riparian vegetation. *Triaenodes ignitus* is widespread and common in streams and rivers across eastern North America. One species, *T. taenia*, occurred only in upper ravine-reaches within the Apalachicola and FAMU Farm study areas. This species was previously thought to be restricted to mountain streams in the southern Appalachians and spring-fed streams in the Piedmont of North Carolina and Alabama (Glover, 1996). The cool-modified ravine microclimate is probably essential for the survival of Florida populations of this Appalachian disjunct. Four *Triaenodes* species (*T. aba*, *T. helo*, *T. ochraceus*, *T. tardus*) were collected only from the Apalachicola study area. *Triaenodes aba* and *T. tardus* are widespread species typically associated with macrophytes in lentic habitats; the occurrence of single individuals of these 2 species indicates they do not typically occur in ravine streams. The southeastern species *T. ochraceus* and the Coastal Plain species *T. helo* were collected from floodplain forest stations (Station A7, A10). Glover (1996) noted that these 2 species have similar habitat preferences, both occurring on cypress roots in small streams. *Triaenodes* n. sp. and *Triaenodes perna* were collected from several Eglin stations. *Triaenodes perna*, a close relative of *T. helo*, ranges over much of eastern North America and can be found in a variety of lotic and sometimes lentic habitats. *Triaenodes* n. sp. is endemic to the Southeastern Coastal Plain, where it is found in small headwater streams. This species, presently being described by Ken Manuel, was listed in Glover (1996) as *Triaenodes* n. sp. A.

Family Limnephilidae

Two species within the genus *Pycnopsyche* (*P. antica*, *P. indiana*) were inventoried. *Pycnopsyche antica* was collected from all regions and study areas and generally was

most abundant at middle and lower reach stations. *Pycnopsyche* species are typically associated with temperate deciduous forests of eastern North America (Ross, 1963), and their life history and biology are closely linked with that of deciduous riparian vegetation. *Pycnopsyche* species are cool-adapted and in Florida restricted to well-shaded streams with substantial groundwater inputs, hence the common and abundant occurrence of *P. antica* in the streams studied. *Pycnopsyche indiana* occurred at only 1 station (E2). In Florida this species has been collected at only a few widely scattered localities (Rasmussen & Denson, 2000).

Family Molannidae

Molannids occurred commonly along the entire lengths of the streams studied. Three species were inventoried (*M. blenda*, *M. ulmerina*, *M. tryphena*), all of which are widespread over much of eastern North America. In this study, clear distinctions were observed in species biotopes and regional distributions. *Molanna blenda* was collected in greatest abundance at ravine-head reaches, while *M. tryphena* more typically occurred at lower reach stations. The zonation was only evident in the panhandle where both species are present. At Gold Head Branch, where it appears that *M. blenda* is absent, *M. tryphena* was more abundant at the steephead reach than at the lower reach on Gold Head Branch. It appears that *M. blenda*, which is noted for primarily inhabiting spring-seeps and small spring-fed streams (Sherberger & Wallace, 1971), competitively excludes *M. tryphena* from upper reaches in areas of sympatry. *Molanna ulmerina* was collected from the western panhandle at only 3 stations (E1, E2, E6). This species also occurs in springruns of north-central Florida, but was not collected at Gold Head Branch.

Family Odontoceridae

Within Florida, *Psilotreta frontalis* is largely restricted to the upper reaches of ravine streams. This species, the only odontocerid known in Florida, was most abundant from ravine-reach stations within the central panhandle region. Both larvae and adults were collected in large numbers at the FAMU Farm Stream. *Psilotreta frontalis* was collected at only 2 stations on Eglin, and these specimens showed interesting variation in the male genitalia, specifically in the development of the styles on segment 9. Specimens from station E5 lacked styles, while specimens from station E2 either lacked styles, possessed normal styles, or possessed short styles. The lack of styles was used by Denning (1948) to distinguish *P. hansoni* from *P. frontalis*. However, Parker and Wiggins (1987), in their revision of the genus, considered the specimens they examined lacking styles to be unusual variants of *P. frontalis*, and found that in all other respects the specimens were identical to typical *P. frontalis*. The variation observed in the Eglin specimens supports the assertion that this is indeed a variable character, and not a valid basis for considering them to be separate species. Furthermore, larvae and pupae collected at station E5 were indistinguishable from those collected at the central panhandle stations.

Family Phryganeidae

Two genera (*Banksiola*, *Ptilostomis*) comprising 3 species (*B. concatenata*, *P. ocellifera*, *P. postica*) were collected in small numbers for this family, whose members, like Limnephilidae, are primarily northern in distribution. *Banksiola concatenata* and *P. ocellifera* each occurred at only 1 Eglin station, while *P. postica* was collected on several occasions from the FAMU Farm stations and at 2 Apalachicola stations.

Family Sericostomatidae

Agarodes species were found to be important components of ravine assemblages throughout upper and lower reaches. Larvae of species within this genus are noted for their burrowing habits and preference for spring-fed, sand-bottom streams. Four species of *Agarodes* were inventoried, including 2 widespread Southeastern species (*A. crassicornis*, *A. libalis*) and 2 narrow-range endemics (*A. logani*, *A. ziczac*). Differences in species composition were apparent at a regional level. *Agarodes crassicornis* was the only species to occur in all study areas. *Agarodes libalis* was collected from the steephead springruns in the Apalachicola study area and from the Gold Head Branch stations. Overall, this species was collected in highest numbers at the Gold Head Branch steephead. *Agarodes ziczac* was restricted to the Eglin study area, where it was widespread and collected in very high numbers. *Agarodes ziczac*, listed by FCREPA as Threatened, occurs only in the western Florida panhandle. Results of this survey, and that of Harris et al. (1982), indicated that the spring-fed headwater streams on Eglin support the highest populations. The protection of headwater areas on the Eglin Air Force Base is vital to long-term health of this species. Even more restricted in distribution is *Agarodes logani*. This species, described by Keth and Harris (1999), is known only from specimens collected within the ravine of the FAMU Farm Stream (Stations F1, F2). The restricted distribution and apparent small population size suggest that this species is particularly vulnerable to extinction. Other headwater spring-fed streams around the type locality need to be sampled in order to better understand its distribution.

Survey Account of Plecoptera

The Plecoptera species inventory, presented in Table 2-6, is discussed below. Overall, 23 species representing 6 families and 13 genera were identified from among the 116 samples taken at the 29 collecting stations. A total of 759 stonefly specimens were identified. The family Perlidae contained the lion's share of species (14), followed by Leuctridae (4), Perlodidae (2), and Nemouridae, Taeniopterygidae, Pteronarcyidae (1 species each). Species richness for the 4 study areas was: Eglin (13 species), Apalachicola (17 species), FAMU farm (4 species), and Gold Head (2 species). Eight species found in the Apalachicola study area were not collected at the other study areas, and 5 species were recorded from only Eglin study area collections. As discussed in the survey account, the distribution of many stonefly species within and among study areas appears to be controlled at the local scale by strict habitat requirements, and at a larger scale by biogeographic affinities. The following account summarizes the survey results. Family subheadings and species are arranged alphabetically under each of the 2 major stonefly groupings, Euholognatha and Systellognatha.

Table 2-6. Survey Summary (Plecoptera).

Species	Collections (n)	Specimens (n)	Study Area (% of Total Specimens) [Collection Station Number]
EUHOLOGNATHA			
Leuctridae			
Leuctra cottaquilla James	4	9	**E**(100)[1,5,8,11]
Leuctra ferruginea (Walker)	3	3	**A**(100)[3,7,9]
Leuctra rickeri James	3	5	**E**(20)[7]; **G**(80)[1,2]
Leuctra triloba Claassen	2	6	**A**(33)[11]; **F**(67)[1]
Neumouridae			
Amphinemura sp.	2	4	**A**(100)[5]
Taeniopterygidae			
Taeniopteryx sp.	1	3	**A**(100)[1]
SYSTELLOGNATHA			
Perlidae			
Acroneuria abnormis (Newman)	1	1	**E**(100)[1]
Acroneuria arenosa (Pictet)	13	71	**E**(7)[4,6]; **A**(93)[1,2,4-6,9,11]
Acroneuria lycorias (Newman)	40	122	**E**(26)[4,5,7,9]; **A**(71)[1-7,9-11]; **F**(3)[1,2]
Agnetina annulipes (Hagen)	4	9	**A**(100)[1]

Table 2-6. Continued.

Species	Collections (n)	Specimens (n)	Study Area (% of Total Specimens) [Collection Station Number]
Eccoptura xanthenes (Newman)	19	49	**A**(22)[3,5,8,9,11,12]; **F**(78)[1]
Neoperla carlsoni Stark & Baumann	1	1	**A**(100)[6]
Neoperla clymene (Newman)	17	311	**E**(0.4)[4]; **A**(0.6)[1,2]; **G**(99)[1,2]
Paragnetina fumosa (Banks)	6	7	**E**(29)[9]; **A**(71)[1,2,4,6]
Paragnetina kansensis (Banks)	1	1	**A**(100)[9]
Perlesta placida (Hagen)	27	67	**E**(52)[1,3,4,6-9,11]; **A**(43)[1,2,5,6,9,11]; **F**(5)[1,2]
Perlesta sp. A	1	2	**E**(100)[5]
Perlesta sp. B	1	1	**E**(100)[6]
Perlinella drymo (Newman)	21	55	**E**(47)[1-4,6,7,9,12]; **A**(53)[2,6-11]
Perlinella zwicki Kondratieff et al.	1	1	**E**(100)[4]
Perlodidae			
Clioperla clio (Newman)	1	1	**A**(100)[1]
Isoperla dicala Frison	1	9	**A**(100)[2]
Pteronarcyidae			
Pteronarcys dorsata (Say)	9	21	**E**(14)[4]; **A**(86)[1,6]

Group Euholognatha (Table 2-6)

Family Leuctridae

Four species of *Leuctra* were inventoried (*L. cottaquilla*, *L. ferruginea*, *L. rickeri*, *L. triloba*). Nymphs of *Leuctra* were sometimes locally abundant, especially in leaf packs within upper reaches; unfortunately nymphs could not be identified to species. Therefore, adult collections from light trapping done during the fall and early spring were used to determine species composition. The fact that adults of *Leuctra* are only present in Florida during the cool months makes them difficult to collect by light, and the low numbers collected in light-trap samples under-represented their true abundance within ravine habitats. Of the four species inventoried, *L. cottaquilla* has the most restricted distribution. This species is endemic to the western Florida panhandle and parts of southern Alabama and Mississippi. Within the Eglin study area, it was widespread and collected at steephead and downstream stations. The other 3 species are widely

distributed in eastern North America. *Leuctra triloba* occurred at upper ravine-reach stations from the Apalachicola and FAMU study areas; these Florida populations are disjunct from its northern range. *Leuctra ferruginea* also occurred in both of these study areas, and in the emergence study at the FAMU Farm Stream (see Chapter 4), both species were found to be syntopic within a 2-m stream section covered by the emergence trap. *Leuctra rickeri* was collected from the Eglin and Gold Head study areas, but not from the central panhandle study areas.

Family Nemouridae

The neumourids were represented by only 2 collections of *Amphinemura* larvae (Station A5). It is likely that these specimens belong to *Amphinemura nigritta*, a species reported nearby and the only known *Amphinemura* species in Florida. *Amphinemura* species, including *A. nigritta*, have a prolonged egg diapause (Stewart & Stark, 2002), which may account for their presence in streams that temporarily go dry. *Amphinemura* in Florida appears to be more characteristic of this stream-type than the permanent, spring-fed systems that were studied.

Family Taeniopterygidae

Taeniopterygidae were represented by only 1 collection (Station A1) comprising 3 nymphs of a *Taeniopteryx* species. As with the other Euholognathans inventoried, nymphs usually are not identifiable to species, hence the genus-level determination. The nymphs likely belong to either *T. lita* or *T. burksi*, the only 2 species known to occur within the central panhandle of Florida.

Group Systellognatha

Family Perlidae

Perlids were, in general, the most common stoneflies collected in the survey, and undoubtedly they play key ecological roles as predators within the ravine ecosystems studied. The family was represented by 14 species grouped within 7 genera. Collections reflected a variety of distributional patterns. Some species inventoried could be considered ecological generalists (e.g., *Perlesta placida*, *Clioperla clio*) while another species, *Eccoptura xanthenes*, appears to have strict ecological requirements met only within the environs of ravine headwaters.

Genus *Acroneuria*. Three *Acroneuria* species were inventoried (*A. abnormis*, *A. arenosa*, *A lycorias*). The widespread North American species, *A. abnormis*, occurred at only Station E1; in Florida it is more common in rivers than from small spring-fed streams. *Acroneuria lycorias*, on the other hand, was common and abundant at panhandle stations, especially within the Apalachicola study area. The Florida panhandle populations are disjunct from the species main-range, which encompasses much of the northern USA and southern Canada east of the Rockies. The absence of this species from other areas on the Southeastern Coastal Plain suggests that it, like many stonefly species, is intolerant of high extremes in water temperature, and that panhandle ravine streams are the key refugia supporting populations on the Southeastern Coastal Plain. *Acroneuria arenosa* occurred at various panhandle stations but differs from *A. lycorias* in that it is found commonly in stream habitats outside of ravine regions. Although *Acroneuria* species do occur within the northern Florida peninsula, none were collected from the

Gold Head study area. The absence of *Acroneuria* from Gold Head Branch may be due to the great abundance of *Neoperla clymene*.

Genus *Agnetina*. Nymphs of *A. annulipes* were collected on several occasions from Flat Creek (Station A1). This species was absent from steephead and upper ravine-reaches.

Genus *Eccoptura*. Closely related to *Acroneuria*, the monotypic genus is thought to represent a specialized lineage adapted to spring-fed headwater streams (Stark & Gaufin 1976). The sole member of the genus, *E. xanthenes*, occurred at steephead and upper-reach ravine stations within the Apalachicola and FAMU Farm study areas. It was particularly abundant within the FAMU Farm ravine. *Eccoptura xanthenes* is common in small, springbrooks of the southern Appalachians, and the cluster of populations occurring in the central panhandle ravines suggests past dispersal between the 2 regions via Apalachicola/Chattahoochee/Flint watershed connections.

Genus *Neoperla*. Two species were inventoried (*N. carlsoni*, *N. clymene*). Both occur in a wide array of lotic habitats; within Florida, *N. carlsoni* is restricted to the western and central panhandle, while *N. clymene* is widely distributed over much of northern Florida. Collections of the 2 species within the panhandle study areas were scant. In contrast, at Gold Head Branch, *N. clymene* was very abundant and the only perlid species to occur.

Genus *Paragnetina*. Two species were inventoried (*P. fumosa*, *P kansensis*). Nymphs of *P. fumosa* were collected at several of the larger streams within the Apalachicola study area, and from Turkey Creek (Station E9) within the Eglin study area. *Paragnetina kansensis* was represented by a single female taken from the Apalachicola

study area (Station A9). Neither species appears to be an important component of upper-reach ravine assemblages.

Genus *Perlesta*. Nymphs of *Perlesta* were commonly collected at virtually all panhandle stations sampled, but unfortunately, nymphs could not be identified to species. Based on adult specimens, 3 species were inventoried (*P. placida*, *Perlesta* sp. A, *Perlesta* sp. B). *Perlesta placida*, which occurs in most Florida panhandle streams and rivers, was widespread and common from panhandle stations. *Perlesta* sp. A and *Perlesta* sp. B were collected from the Eglin study area (Station E5 and E6, respectively). *Perlesta* sp. A was represented by 2 females and *Perlesta* sp. B by 1 male. The specimens were sent to Dr. Bill Stark for examination, who concluded that they likely belong to new species, but that additional specimens are needed for further study. Because 1 collection comprised females and the other collection was a male specimen, it is possible that the specimens are of the same species.

Genus *Perlinella*. Adults of *Perlinella* were commonly taken in light-trap samples from the Eglin and Apalachicola study areas. Two species were inventoried (*P. drymo* and *P. zwicki*). *Perlinella drymo* was common at upper- and lower reach stations within both Eglin and Apalachicola study areas, while *P. zwicki* was represented by a single male specimen taken from Juniper Ck (Station E4). *Perlinella zwicki*, a Coastal Plain endemic, more commonly occurs in shifting-sand-bottom rivers such as the Blackwater, while *Perlinella drymo*, an eastern species, occurs in a wider array of habitat types, including small headwater streams.

Family Perlodidae

Only 2 species of perlodids were collected, *Clioperla clio* and *Isoperla dicala*, both from the Apalachicola study area. A larva of *C. clio* was collected from Flat Creek (Station A1), and adults of *I. dicala* were taken from Crooked Creek (Station A2). *Clioperla clio* occurs across many stream types in northern Florida but apparently is not an important component of ravine assemblages. *Isoperla dicala* is rarer within the state and is known from only a few panhandle streams and rivers.

Family Pteronarcyidae

Pteronarcys dorsata was collected at several lower-reach stations (Stations E4, A1, A6). Larvae were collected from areas of fast flow where leaf packs accumulated on snags. This species, widespread in North America, is restricted in Florida to clean, unpolluted streams and rivers with fast flow. *Pteronarcys dorsata* did not occur in the upper reaches of ravine streams.

CHAPTER 3
ANALYSIS OF TRICHOPTERA COMMUNITY STRUCTURE AND ENVIRONMENTAL RELATIONSHIPS

Based on results of the biodiversity survey of ravine streams across northern Florida (Chapter 2), it was apparent that there are significant differences in species composition of the caddisfly and stonefly fauna among the different sampling stations. Examples of faunal differences between stations and study areas were noted in the survey account, and species occurrence was generally discussed in terms of species geographic distributions and habitat associations (e.g., stream size, substrate microhabitats).

From the starting point of understanding the makeup of the stonefly and caddisfly fauna of the various stations, additional questions can be asked such as: How similar or different is the fauna between stations? Can the survey results be used to produce a classification of community types, and if so, what species define a particular community? What geographic and environmental factors best explain the faunal differences observed among stations? In an attempt to address these questions, the survey data were analyzed using multivariate statistical methods. The objectives of the analysis were to i) provide a classification and description of community types based on faunal similarities between stations; and ii) investigate key geographic and environmental factors that are predictors of species composition.

Materials and Methods

Data Set

The faunal survey (see Chapter 2), which resulted in a rather large data set of species occurrences and abundance values from 29 stations, was used as the starting point in this analysis. The data set analyzed was limited to caddisfly data, with the stonefly data excluded from the analyses because of the relatively low species diversity and small sample-sizes. The low stonefly numbers were in part due to inherent lower diversity and in part due to the sampling bias that resulted from the heavy reliance on light trapping, which is ineffective for capturing many stonefly species. The data for microcaddisflies (Family: Hydroptilidae) were excluded from the analyses because species composition and abundance data (counts), unlike non-hydroptilid data, were not available for all blacklight samples. The data set used was further confined to only those stations from which at least 3 light-trap samples were collected (2 spring/summer samples, and 1 fall sample). This requirement resulted in 9 stations being dropped from the analyses (E8, E10-12, A1, A5, A8, A12, F3), leaving the final data set consisting of abundance values for 72 macrocaddisfly species from 20 stations. Abundance was recorded as the total number of individuals/species collected at each station. The data set was analyzed using 2 statistical approaches: classification and ordination. Statistical procedures were performed using the computer software MVSP (Kovach, 1999).

Classification

Stations were classified on the basis of faunal similarity using the clustering technique Unweighted Pair Group Mathematical Averaging (UPGMA). The purpose of performing a cluster analysis was to measure similarity of macrocaddisfly faunas among

stations, and to group like faunas into a framework from which community structure and relationships could be inferred. Similarity among stations was measured as the Spearman rank order correlation coefficient (r_s), which is computed as follows:

$$r_s = 1 - \frac{6\sum_{k=1}^{n} (R_1 - R_2)^2}{n(n^2 - 1)}$$

where: R_1 and R_2 = station pair abundance rank order; k = species abundance; n = total number of species.

A quantitative measure (i.e., Spearman's Coefficient) was chosen over binary (presence/absence) similarity measures (e.g., Jaccard) because species varied greatly in relative abundance among stations; therefore, a presence/absence coding of the data would not be sensitive to these differences. Spearman rank correlation coefficient was used instead of other quantitative similarity measures because this procedure uses rank order of abundance instead of raw totals for abundance. Rank ordering of abundance is particularly useful in this study because sampling effort (e.g., number of light trap samples) was not equal among all stations, thus species total abundance values were not always directly comparable between stations; however, by converting abundance to a rank order, the relative abundance rankings could be used for faunal composition comparisons among stations. From the Spearman similarity matrix, the widely used clustering procedure Unweighted Pair Group Mathematical Averaging (UPGMA) was used to group stations with like caddisfly faunas into a hierarchy of nested sets. The results of this analysis, depicted as a dendogram, are used to propose a classification hypothesis of community structure. Community species composition was characterized by providing a list of relative abundances for species occurring in each community.

Ordination

An alternative approach to classifying (clustering) station faunas into discrete groups, which one may infer to represent ecological communities, is to consider that species composition changes in a more continuous fashion in response to environmental gradients (e.g., latitude/longitude, altitude, temperature, stream size). Taking this approach, the stations were ordinated on the basis of their macrocaddisfly faunas to see if the data were structured in such a way that can be related to environmental gradients present within the study area. The procedure used, Detrended Correspondence Analysis (DCA), is widely used with ecological data and has advantages over other ordination techniques in that both species and station ordinations are produced simultaneously, and the axes are scaled in standard deviation units that have a definite meaning (Hill & Gauch, 1980). According to Hill (1979), samples separated by more than 4 standard deviations will in general have no species in common. Detrended Correspondence Analysis also is favored over other ordination techniques because it eliminates the "arch" effect caused by interdependence of axis 1 and axis 2.

Results and Discussion

The results of the data analyses showed that ravine assemblages surveyed from across northern Florida support a macrocaddisfly fauna that can be classified into distinct communities. The communities exhibit major differences in species composition that can be related to geographic region and habitat types. These differences in community structure attributed to geographic and habitat factors are structured hierarchically. The large and biogeographically diverse area encompassing the study areas acts as a geographic template, determining to a large extent the caddisfly fauna of the 3 geographic

regions (i.e., western panhandle, central panhandle, peninsula). The faunas among regions are sufficiently distinct that stations within regions were more similar to each other, regardless of habitat factors, than to stations in other regions. Nested within this geographic template is a habitat template that acts to further shape and define the fauna into recognizable communities. Discussed below are results of the classification and ordination analysis as it applies to my interpretation of community structuring.

Community Classification

The similarity matrix (Table 3-1) and UPGMA dendogram (Fig. 3-1) quantify the degree of similarity in the macrocaddisfly faunal composition among stations. Any 2 stations can be compared by reading the similarity matrix. The dendogram illustrates the results of the UPGMA analysis. Stations were grouped into a hierarchical framework that is informative and useful for proposing a community classification. The dendogram shows that the 2 highly similar (0.77) peninsular stations at the Gold Head Branch steephead represent a distinct community showing little similarity (0.1) to stations constituting the panhandle grouping. Likewise, within the panhandle, the Eglin steephead streams in the western panhandle showed little similarity (0.15) to the central panhandle station cluster. Within the central panhandle, additional groupings were evident with large streams within the Apalachicola study area showing only slight similarity (0.27) to small ravine-headwater streams. The ravine headwater streams, although modestly similar (0.48), do appear to represent 2 distinct community types, corresponding to clayhill ravine streams (0.60) and Apalachicola steephead streams (0.62). The Eglin steephead stream portion of the dendogram suggests that the Eglin stations are not separable into distinct communities but rather represent a single diverse community.

Based on this interpretation of the analysis, 5 distinct communities are recognized within the data set: Gold Head Branch, Apalachicola Steephead Streams, Clayhill Ravine Streams, Apalachicola Large Streams, and Eglin Steephead Streams. Community composition is characterized in terms of what species are present and their relative abundance (Tables 3-2 and 3-3). These parameters are also used in discussing community diversity, in that they delimit species richness and eveness. The abundance distribution for species constituting the different communities is shown in Figure 3-2. Data regarding the 5 communities are summarized and discussed below.

Table 3-1. Matrix of Spearman rank abundance correlation coefficients for macrocaddisfly data analyzed in the cluster analysis.

	E1	E2	E3	E4	E5	E6	E7	E9	A2	A3	A4	A6	A7	A9	A10	A11	F1	F2	G1	G2
E1	1																			
E2	0.54	1																		
E3	0.65	0.53	1																	
E4	0.62	0.67	0.71	1																
E5	0.60	0.57	0.55	0.59	1															
E6	0.51	0.67	0.48	0.68	0.55	1														
E7	0.63	0.67	0.68	0.75	0.57	0.68	1													
E9	0.40	0.51	0.45	0.53	0.35	0.64	0.65	1												
A2	0.04	-0.10	0.03	0.07	0.03	0.15	0.11	0.14	1											
A3	0.25	0.26	0.34	0.26	0.30	0.12	0.26	-0.02	0.23	1										
A4	-0.05	-0.22	-0.08	-0.04	-0.15	-0.07	-0.08	-0.11	0.61	0.15	1									
A6	0.03	-0.09	-0.04	0.02	0.06	0.13	0.08	0.06	0.80	0.20	0.56	1								
A7	0.22	0.12	0.41	0.32	0.26	0.20	0.29	0.14	0.42	0.48	0.26	0.33	1							
A9	0.34	0.22	0.48	0.40	0.36	0.20	0.31	0.07	0.37	0.54	0.15	0.24	0.66	1						
A10	0.15	0.07	0.33	0.24	0.14	0.13	0.24	0.11	0.43	0.36	0.30	0.38	0.76	0.53	1					
A11	0.39	0.15	0.40	0.29	0.36	0.15	0.34	0.14	0.39	0.51	0.30	0.35	0.72	0.66	0.59	1				
F1	0.19	0.05	0.35	0.18	0.32	0.02	0.21	0.03	0.31	0.62	0.20	0.24	0.57	0.63	0.40	0.54	1			
F2	0.18	0.05	0.29	0.10	0.29	-0.04	0.13	-0.10	0.18	0.58	0.13	0.15	0.49	0.45	0.36	0.40	0.78	1		
G1	-0.02	-0.04	0.12	0.01	-0.12	0.05	0.07	0.09	0	0.09	0.02	0.07	0.27	0.08	0.31	0.10	0.09	0.11	1	
G2	0.07	0.01	0.15	0.04	-0.10	0.09	0.11	0.15	0.08	0.12	0.04	0.18	0.30	0.16	0.33	0.13	0.12	0.18	0.77	1

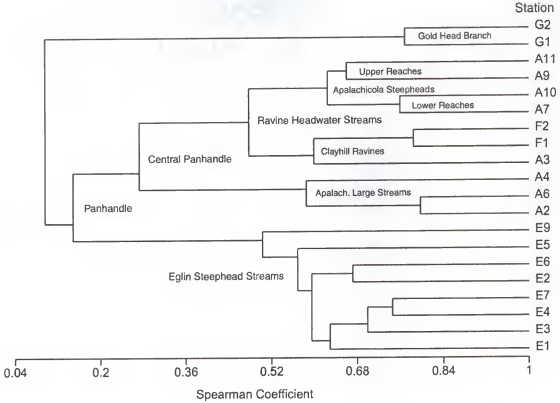


Figure 3-1. Results of UPGMA cluster analysis of sampling stations using Spearman's rank order correlation coefficient as the measure of similarity. Analysis was of the macrocaddisfly data obtained in the survey.

Gold Head Branch

The plot (Fig. 3-2) of species abundance values indicated in Tables 3-2 and 3-3 illustrates that the macrocaddisfly community at the Gold Head Branch springrun is structured very differently than the other communities. This community is characterized by low species richness (n=21) and highly uneven abundance distribution, as indicated by the short and steeply sloping line in Figure 3-2. Despite high-quality habitat of the stream and presumed wide-breadth of niches, the community is numerically dominated by a relative few species. In part, this can be explained by the lower caddisfly species richness of the peninsula versus the panhandle. However, I have collected many other caddisfly species, and also stonefly species, from small spring-fed streams in the northern

peninsula that I expected to also be present in Gold Head Branch. The low diversity of the Gold Head Branch community may be due in part to the small size of the watershed (a short ravine-springrun which ends in a lake); therefore, opportunities for species to colonize Gold Head Branch are limited. Additionally, land use in the area related to park development and visitor use, and previous mill operations during the 1930's that included a dam across the stream, may have caused species extirpations. The Gold Head Branch community does, however, contain some unique faunal elements, most notable being the population of *Diplectrona* sp. A that inhabits the upper reach of the ravine head. Protection of the steephead from human disturbance is essential to maintain the health of this species, which is known from only this locality.

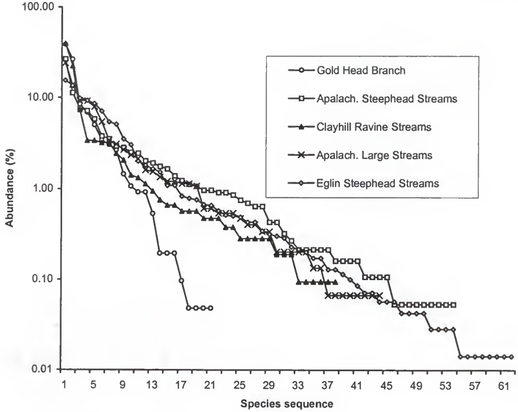


Figure 3-2. Species abundance plots for the 5 macrocaddisfly communities. Species abundance values according to those listed in Tables 3-2 and 3-3.

Apalachicola steephead streams

The springruns of steephead ravines on the Nature Conservancy Preserve support a species-rich macrocaddisfly community (54 species) that includes a number of ravine crenobionts, narrow-range endemics, and disjuncts, as well as widespread habitat generalists. The numerical dominance of *Hydropsyche incommoda* reflects the strong influence of the Apalachicola River on this community. Despite the river's clear faunal influence, the community's ravine affinity is strong with ravine crenobionts such as *Diplectrona modesta*, *Heteroplectron americanum*, *Psilotreta frontalis*, and *Molanna blenda* all occurring in significant numbers. Species that set this community apart include *Lepidostoma griseum*, a disjunct species known from no other area of Florida. The abundance of *Hydropsyche elissoma* and *Chimarra falculata* also distinguishes Apalachicola steephead streams from clayhill ravine streams. The substantial contributions of springs to the stream flows, a result of high groundwater storage capacity of the sandhills, is likely a key factor, as these 2 species are also abundant within Eglin's steephead springruns.

Clayhill ravine streams

The 3 stations sampled at small clayhill ravine streams in the central panhandle have a macrocaddisfly community that is somewhat less diverse both in terms of species richness (38 species) and eveness than the other panhandle communities sampled. Ravine crenobionts and other caddisflies associated with small spring-fed streams in the Florida panhandle (e.g., *Psilotreta frontalis*, *Diplectrona modesta*, *Anisocentropus pyraloides*, *Molanna blenda*, *Phylocentropus lucidus*, *Lepidostoma serratum*) are among the most abundant species. Absent, or far less abundant, are hydropsychids typical of the large

streams and rivers (e.g., *Hydropsyche incommoda*, *Cheumatopsyche pinaca*, *Hydropsyche rossi*). The community also contains 2 interesting elements: *Agarodes logani*, a narrow-range endemic, and *Triaenodes taenia*, an Appalachian disjunct. *Psilotreta frontalis* is especially abundant in this community.

Apalachicola large streams

The large streams of the Apalachicola Bluffs and Ravines Region have a caddisfly community showing little similarity to headwater ravine communities. The community has an especially diverse leptocerid component, with 6 of the 10 most abundant species belonging to this family. In this respect, the Apalachicola large stream community more generally reflects the warm-adapted fauna of Florida as a whole. The 2 most abundant species included the large river species, *Hydropsyche incommoda*, and a habitat generalist, *Cheumatopsyche pinaca*. Generally absent are ravine crenobionts and Appalachian disjuncts, suggesting that habitat and water quality parameters such as temperature are sufficiently different from ravine headwaters so that the structure of this community shows little resemblance to that of the small-stream ravine communities of the central panhandle.

Eglin steephead streams

The caddisfly community of Eglin's steephead ravines and high volume springruns is distinct and arguably contains the highest concentration of narrow-range endemic caddisflies anywhere on the Southeastern Coastal Plain. Ravine crenobionts of this community include species typical of other panhandle ravines such as *Diplectrona modesta*, *Molanna blenda*, *Heteroplectron americanum*, *Psilotreta frontalis*, and *Lepidostoma serratum*. In addition, to this list can be added another ravine crenobiont, a

new species within the genus *Beraea*. However, what sets the Eglin steephead stream community most apart from the other communities are the other narrow-range endemics, 3 of which (*Micrasema* n. sp., *Agarodes ziczac*, *Nectopsyche paludicola*) were the most abundant species within this community. Additional narrow-range endemics such as *Cheumatopsyche gordonae*, *Cheumatopsyche petersi*, *Nyctiophylax morsei*, and *Polycentropus floridensis* are important and unique components of this community, which are not present in central panhandle or peninsular ravine ecosystems. In total, 20 species of macrocaddisflies occurred only in the Eglin steephead stream community (Table 3-2)—the other 4 communities each contained only 4 or 5 such species.

The origin and persistence of this unique community appears to be related to both geographic and habitat factors. The large and insular area encompassing Eglin's steephead drainage networks contains enough unique stream habitat to act effectively as an "evolutionary engine" driving speciation. The many narrow-range endemics found on Eglin appear to have adapted to these rather specialized conditions to such an extent as to limit their abilities for dispersal and colonization to widespread areas. Means (2000) hypothesized that past sea-level changes may have acted as an isolating mechanism on ancestral stocks of Plethodontid salamander populations in steepheads near the coast such as those on Eglin. Means (2000) suggested that for the steephead ravines on the western side of Eglin a slight increase in sea level (2-5 meters) would have resulted in the embayment of the Yellow River, thus causing a saltwater barrier to isolate ancestral salamander populations within the coastal steephead valleys. It seems plausible that this isolating mechanism could also be a factor contributing to the area's high degree of caddisfly endemism.

Table 3-2. Macrocaddisfly species composition for Gold Head and Eglin steephead stream communities, abundance of each species given as percent of total specimens collected. Note: * denotes species recorded from only 1 community.

Gold Head Branch		**Eglin Steephead Streams**		**Eglin -continued**	
Species (n=21)	(%)	Species (n=62)	(%)	Species	(%)
Cheumatopsyche pinaca	38.41	**Micrasema* n. sp.	15.41	**Triaenodes* n. sp.	0.09
Nectopsyche pavida	26.32	**Agarodes ziczac*	13.51	*Cheumatopsyche pettiti*	0.07
Agarodes libalis	8.47	**Nectopsyche paludicola*	9.79	*Oecetis ditissa*	0.07
Triaenodes ignitus	6.87	*Diplectrona modesta*	9.28	**Beraea* n. sp.	0.06
Chimarra florida	5.03	*Oecetis inconspicua* Comp.	8.59	*Oecetis osteni*	0.06
Pycnopsyche antica	3.43	*Lype diversa*	7.08	*Oecetis persimilis*	0.06
Chimarra aterrima	3.05	*Chimarra falculata*	5.42	*Phylocentropus placidus*	0.04
Oecetis georgia	2.66	*Oecetis sphyra*	5.09	*Cheumatopsyche edista*	0.04
Micrasema wataga	1.45	*Anisocentropus pyraloides*	3.52	*Nyctiophylax serratus*	0.04
Polycentropus blicklei	1.06	**Cheumatopsyche gordonae*	3.04	*Oecetis cinerascens*	0.04
**Diplectrona* sp. A	0.92	*Hydropsyche elissoma*	2.01	*Hydropsyche incommoda*	0.03
Molanna tryphena	0.92	*Molanna blenda*	1.81	*Neureclipsis crepuscularis*	0.03
Oecetis inconspicua Comp.	0.53	*Pycnopsyche antica*	1.65	*Oecetis daytona*	0.03
Nyctiophylax serratus	0.19	**Macrostemum carolina*	1.53	**Ptilostomis ocellifera*	0.03
Polycentropus cinereus	0.19	*Brachycentus chelatus*	1.08	*Cheumatopsyche burksi*	0.01
Agarodes crassicornis	0.19	*Heteroplectron americanum*	1.08	*Hydropsyche rossi*	0.01
**Hydropsyche decalda*	0.10	*Rhyacophila carolina*	0.83	**Cernotina calcea*	0.01
**Cernotina truncona*	0.05	**Cheumatopsyche petersi*	0.78	*Ceraclea protonepha*	0.01
**Polycentropus clinei*	0.05	*Chimarra florida*	0.76	**Nectopsyche candida*	0.01
Oecetis daytona	0.05	*Agarodes crassicornis*	0.67	*Oecetis nocturna*	0.01
Oecetis osteni	0.05	*Chimarra moselyi*	0.66	**Pycnopsyche indiana*	0.01
		Nectopsyche pavida	0.57	**Banksiola concatenata*	0.01
		Chimarra aterrima	0.51		
		**Ceraclea diluta*	0.50		
		**Nyctiophylax morsei*	0.48		
		**Neureclipsis melco*	0.43		
		Polycentropus cinereus	0.43		
		**Polycentropus floridensis*	0.34		
		Cheumatopsyche virginica	0.31		
		Psilotreta frontalis	0.30		
		Triaenodes ignitus	0.29		
		Oecetis georgia	0.23		
		**Molanna ulmerina*	0.21		
		Nectopsyche exquisita	0.20		
		Ceraclea maculata	0.17		
		**Triaenodes perna*	0.17		
		Lepidostoma serratum	0.13		
		**Ceraclea resurgens*	0.13		
		Molanna tryphena	0.11		
		Phylocentropus carolinus	0.10		

Table 3-3. Macrocaddisfly species composition for central panhandle communities, abundance of each species given as percent of total specimens collected. Note: * denotes species recorded from only 1 community.

Apalach. Steephead Streams		**Clayhill Ravine Streams**		**Apalach. Large Streams**	
Species (n=54)	(%)	Species (n=38)	(%)	Species (n=44)	(%)
Hydropsyche incommoda	26.6	*Psilotreta frontalis*	39.5	*Hydropsyche incommoda*	23.9
Diplectrona modesta	11.3	*Diplectrona modesta*	22.2	*Cheumatopsyche pinaca*	13.8
Anisocentropus pyraloides	7.6	*Anisocentropus pyraloides*	7.3	*Oecetis sphyra*	9.2
Oecetis inconspicua Comp.	7.2	*Oecetis inconspicua* Comp.	3.4	*Ceraclea tarsipunctata*	9.2
Hydropsyche rossi	5.8	*Molanna blenda*	3.4	*Ceraclea protonepha*	7.9
Agarodes libalis	3.8	*Phylocentropus lucidus*	3.2	*Triaenodes ignitus*	5.4
Pycnopsyche antica	3.5	*Cheumatopsyche pettiti*	3.2	*Oecetis inconspicua* Comp.	3.4
Hydropsyche elissoma	2.9	*Lype diversa*	2.4	*Ceraclea transversa*	3.1
Psilotreta frontalis	2.8	*Lepidostoma serratum*	2.1	*Hydropsyche rossi*	2.7
Chimarra falculata	2.5	*Triaenodes ignitus*	1.4	*Anisocentropus pyraloides*	2.3
Chimarra aterrima	2.5	*Oecetis sphyra*	1.3	*Oecetis persimilis*	2.1
Oecetis sphyra	2.0	*Rhyacophila carolina*	1.1	*Phylocentropus carolinus*	1.6
Triaenodes ignitus	1.9	*Leptocerus americanus*	0.9	*Nectopsyche exquisita*	1.5
Nectopsyche exquisita	1.8	*Oecetis ditissa*	0.8	*Ceraclea cancellata*	1.3
Molanna tryphena	1.7	*Lepidostoma latipenne*	0.7	*Potamyia flava*	1.2
Heteroplectron americanum	1.4	**Triaenodes taenia*	0.7	*Ceraclea maculata*	1.2
Lype diversa	1.2	*Cheumatopsyche pinaca*	0.6	*Lype diversa*	1.1
Molanna blenda	1.1	*Chimarra aterrima*	0.6	**Ceraclea nepha*	1.1
Cheumatopsyche pinaca	1.1	*Polycentropus cinereus*	0.6	*Cheumatopsyche campyla*	1.1
Cheumatopsyche pettiti	1.0	*Cheumatopsyche edista*	0.5	*Cheumatopsyche edista*	0.6
Rhyacophila carolina	1.0	*Pycnopsyche antica*	0.5	*Leptocerus americanus*	0.6
Phylocentropus lucidus	0.9	**Agarodes logani*	0.5	*Nectopsyche pavida*	0.5
Polycentropus cinereus	0.9	*Chimarra obscura*	0.4	*Oecetis cinerascens*	0.5
Cheumatopsyche edista	0.9	*Ceraclea transversa*	0.4	*Oecetis osteni*	0.5
Phylocentropus carolinus	0.7	*Phylocentropus carolinus*	0.3	*Pycnopsyche antica*	0.5
**Lepidostoma griseum*	0.7	**Nyctiophylax affinis*	0.3	*Phylocentropus placidus*	0.4
Chimarra florida	0.6	*Polycentropus blicklei*	0.3	*Cheumatopsyche pettiti*	0.4
Oecetis georgia	0.6	*Oecetis georgia*	0.3	*Polycentropus cinereus*	0.3
Oecetis ditissa	0.4	*Ptilostomis postica*	0.3	*Heteroplectron americanum*	0.3
Agarodes crassicornis	0.4	**Hydropsyche betteni*	0.2	*Hydropsyche elissoma*	0.2
Ceraclea maculata	0.3	*Heteroplectron americanum*	0.2	*Chimarra moselyi*	0.2
Oecetis persimilis	0.3	*Oecetis osteni*	0.2	*Oecetis georgia*	0.2
Potamyia flava	0.2	*Cheumatopsyche burksi*	0.1	*Oecetis nocturna*	0.2
Neureclipsis crepuscularis	0.2	*Hydropsyche elissoma*	0.1	**Triaenodes tardus*	0.2
Lepidostoma latipenne	0.2	*Hydropsyche incommoda*	0.1	*Diplectrona modesta*	0.1
Oecetis nocturna	0.2	*Oecetis nocturna*	0.1	*Molanna tryphena*	0.1
**Triaenodes helo*	0.2	*Molanna tryphena*	0.1	*Phylocentropus lucidus*	0.1
Cheumatopsyche virginica	0.2	*Agarodes crassicornis*	0.1	*Neureclipsis crepuscularis*	0.1
Micrasema wataga	0.2			*Nyctiophylax serratus*	0.1
Ceraclea cancellata	0.2			*Polycentropus blicklei*	0.1
Oecetis osteni	0.2			**Ceraclea flava*	0.1
Cheumatopsyche campyla	0.1			**Ceraclea ophioderus*	0.1
Chimarra obscura	0.1			*Ptilostomis postica*	0.1
Brachycentus chelatus	0.1			*Rhyacophila carolina*	0.1
Ceraclea tarsipunctata	0.1				
Phylocentropus placidus	0.1				
**Cernotina spicata*	0.1				
Polycentropus blicklei	0.1				
Ceraclea protonepha	0.1				
Nectopsyche pavida	0.1				
Oecetis cinerascens	0.1				
**Triaenodes aba*	0.1				
**Triaenodes ochraceus*	0.1				
Ptilostomis postica	0.1				

Ordination Analysis

The results of the detrended correspondence analysis used to ordinate sampling stations are presented in Figures 3-3 to 3-5. The first ordination (Fig. 3-3) is for all 20 stations. This analysis resulted in stations being ordinated along 5 axes with eigenvalues of 0.65, 0.35, 0.14, 0.05, and 0.03, respectively. The stations as plotted along the first 2 axes shown in Figure 3-3 account for about 35% of the variation in the data. Because of the presence of additional axes beyond axis 1 and 2, interpretation of the graph is rather tenuous. However, it does appear that in general axis 1 is related to a geographic gradient (longitude), and axis 2 is related to a stream-size gradient. This assessment is in general agreement with the cluster analysis, wherein basal groupings corresponded with station location within a particular region (western panhandle, eastern panhandle, and peninsula).

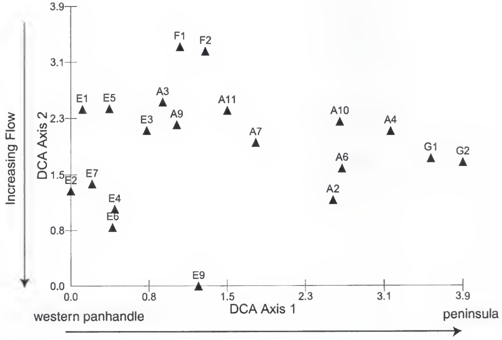


Figure 3-3. Scatter plot of DCA ordination of 20 stations across northern Florida. Analysis based on macrocaddisfly survey data.

The wide spread of the central panhandle stations along axis 1, however, indicates that longitude alone does not explain station placement along axis 1.

In order to investigate gradients related to habitat variables more closely, the western panhandle and central panhandle stations were separately ordinated to remove the effect region imparts on the ordination. Both ordinations (Figs. 3-4 and 3-5) indicated that variation between stations is largely explained in terms of a stream-size gradient. For the ordination of Eglin stations (Fig. 3-4), axis 1 explained about 43% of the variation in station scores. In this graph, upper reach stations are placed at one end axis 1 and Station E9, the station with greatest discharge, at the other end; stations from middle reaches were clustered about midway along axis 1. A similar result was obtained for the central panhandle stations (Fig. 3-5). In this ordination, axis 1 explained about 38% of the variation in station scores. Large stream stations were placed at one end of the axis and ravine headwater reaches at the other end.

Results of both cluster analysis and ordination suggest that caddisfly community composition is controlled both by geographic and habitat factors. The study areas, which span much of northern Florida, are distant enough from one another that the geographic ranges of many species do not include all study areas. The diverse array of component species geographic distributions acts as a base template upon which community composition is structured. From this template, species composition at a given site is then fine-tuned by habitat factors related to stream size and ravine type.

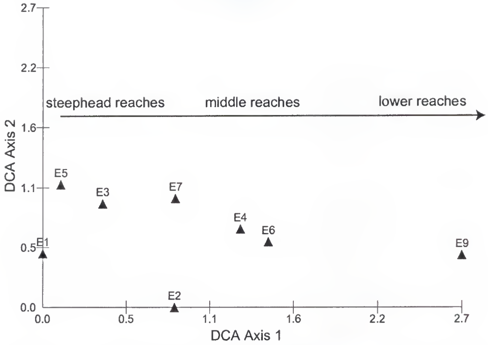


Figure 3-4. Scatter plot of DCA ordination of steephead stream stations on Eglin Air Force Base in the western panhandle. Analysis based on macrocaddisfly survey data.

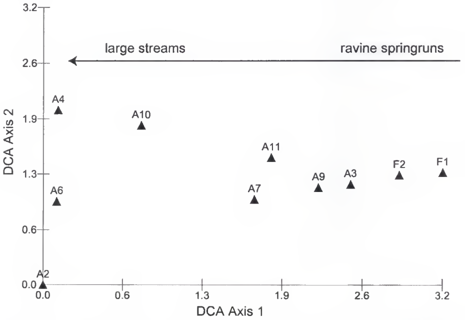


Figure 3-5. Scatter plot of DCA ordination of central panhandle stations. Analysis based on macrocaddisfly data.

CHAPTER 4
TRICHOPTERA AND PLECOPTERA FLIGHT SEASONALITY, AND ADULT EMERGENCE IN A RAVINE SPRINGRUN

Information regarding adult emergence and flight seasonality is of key importance to the study of caddisfly and stonefly life histories. The adult stage is a relatively short-lived life stage when caddisflies and stoneflies must emerge, find mates, and oviposit. Additionally, it is during the adult stage when dispersal to new habitats is greatest. Despite the biological importance of the adult stage, relatively little is known of the biology of adults as compared to larvae. Because the survey resulted in large numbers of adult collections, these data can provide important baseline data on flight seasonality for the species and populations that were sampled. Towards this goal, collection dates were examined and flight seasonality was characterized for various species recorded in the survey. Additionally, species diversity and emergence phenology of caddisfies and stoneflies inhabiting the ravine springrun at the FAMU Farm study area were investigated using emergence traps.

Materials and Methods

Observed Flight Seasons

Flight seasonality was characterized for caddisfly and stonefly species inventoried as a part of the biodiversity survey of ravine ecosystems in northern Florida (Chapter 2). A description of ravine habitats and the stream systems surveyed for caddisflies and stoneflies is presented in Chapter 1, included are maps (Figs. 1-1 to 1-5) showing the locations of the 4 study areas and 29 sampling stations. The monthly occurrence of adult

caddisfly and stonefly species was obtained from the adult collection data obtained in the survey. Data on monthly occurrences for each species from all 29 sampling stations were combined and tabulated in order to give a general picture of adult flight-seasonality for each species within the study area as a whole. Adult specimens were captured primarily by light trapping and mainly during spring and fall. No light trapping was done during January, February, and July. The number of light-trap samples collected in each month is as follows: March (20), April (26), May (14), June (22), August (4), September (3), October (15), November (8), December (4).

Emergence Study

The emergence study was conducted at the FAMU Farm study area (Fig. 1-4) within a ravine located on the property of the Florida A&M University Research and Extension Center in Gadsden County (see Chapter 1 for a description of the study area). Adult aquatic insects emerging from the ravine springrun at the FAMU Farm were sampled using emergence traps. The aquatic insect emergence trap used (BioQuip® Item No. 2829) (Fig. 4-1) consisted of a 2.4-m-high tent structure suspended over a 4 m^2 area. The front and back of the trap is cut 0.4 m shorter than the sides so that water is able to flow under without obstruction. The traps were

Figure 4-1. Emergence Trap 1 installed over the FAMU farm springrun, near the ravine head.

each suspended over the stream from parachute cord tied between 2 trees. The sides and corners were staked so the bottom flaps were in contact with the stream bank on the sides and in contact with the stream surface in the front and back, thereby preventing emergent insects from escaping. Aquatic larvae were not confined and could move into or out from under the traps. The tent material consisted of Lumite screen with 32 x 32 mesh (530 micron openings). Access to the inside of the trap was through a 1.2 m slit-opening sealed with Velcro.

Two traps were deployed over the FAMU Farm ravine springrun. Trap 1 was located about 20 meters below the base of the ravine head, and Trap 2 was placed about 70 meters below the ravine head. The composition of benthic substrate within Trap 1 was estimated to consist of sand (45%), gravel (20%), mud/silt (15%), snags/leaf packs (15%) and roots (5%). Substrate within Trap 2 comprised sand (65%), roots (15%), mud/silt (10%), gravel (5%) and snags/leaf packs (5%). Trap 1 was installed 12 March 1998 and samples collected until May 24th after which time the cord used to suspend the trap broke due to an unknown reason, causing the trap to collapse. The trap was then reinstalled on 25 June 1998, and sampling continued for a full year until 5 July 1999. Trap 2 was installed 31 March 1999 and deployed until 5 July 1999.

Insect samples from each trap were collected at about 10-day intervals, resulting in 41 samples from Trap 1 and 8 samples from Trap 2. Stonefly and caddisfly adults trapped within the tent were collected by aspiration for smaller specimens and by using a soft-touch forceps for capturing larger specimens. All specimens were placed in 80% ethyl alcohol. Usually the insects were found resting either at the peak or on the sides and corners of the trap. Sufficient time (usually about 25 minutes) was spent searching and

collecting within the tent until no additional specimens could be found. Significant numbers of emergent insects were likely missed in sampling as a result of mortality during sampling intervals due to spider predation and other mortality factors.

Specimen identification and data analysis. Trichoptera and Plecoptera specimens collected from the emergence traps were identified to species in most cases. The microcaddisflies (Family:Hydroptilidae) were identified by Dr. Steven Harris, and I identified all other specimens. Synoptic voucher collections will be deposited at the following collections: Florida A&M University Aquatic Insect Collection, Clemson University Arthropod Collection, and the personal collection of the author. The deposition of type material for *Hydroptila sykorai* is given in Harris (2002). For each sample, the number of males and females of each species were recorded. Collection data were tabulated, and emergence phenology for the most abundant species was graphed.

Results and Discussion

Observed Flight Seasons (Trichoptera)

In warm temperate climates such as found in northern Florida, adult caddisflies are potentially present at any time of year, and as expected, specimens were collected during all months when light trapping was conducted. Based on the monthly occurrence data from the survey, species could be grouped into 3 flight-season categories: spring/summer species (S), fall species (F), and those species with extended flight seasons (E) (Table 4-1). Species with fewer than 4 occurrences were not classified as to their flight seasonality. The highest number of species fell into the extended fight season category (68 spp.), followed by spring/summer species (28 spp.) and fall species (1 sp.).

Spring/summer species. The 28 species in this group were collected only during the

spring and summer months (March-September). Some species within this grouping appeared to be early spring species such as *Ceraclea resurgens*, while most species occurred as adults throughout spring (March-May) and into the summer period (June-September). The low number of samples collected during July, August, and September make it difficult to determine the extent of species still present as adults during the late-summer period.

Because sampling intensity was greatest in the spring, results from this period were examined separately for patterns and trends in species occurrences. During the spring light-trapping period, caddisfly species richness was highest in May with a total of 105 species being collected, April samples accounted for 96 species, followed by June (81 spp.) and March (67 spp.). Some differences were noted between major groups of caddisflies in terms of changes in species richness throughout the spring months (Fig. 4-2). Relatively few leptocerid species were present in March, followed by a sharp increase in leptocerid species richness to a peak in April, and then a gradual decrease in May and

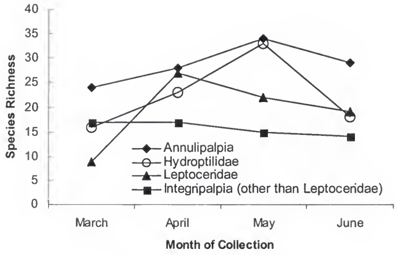


Figure 4-2. Caddisfly species richness recorded from light trap samples collected during spring months. Number of samples (n) for each month as follows: March (20), April (26), May (14), June (22).

June samples. Hydroptilid species richness increased steadily to a peak in May, followed by a sharp decrease in richness in the June samples. Integripalpia (other than Leptoceridae) were present at fairly constant levels of species richness throughout the spring, while the annulipalpians showed a gradual increase to a peak in May followed by a gradual drop off in species richness in June samples. Most of the cool-adapted species fall into these last 2 groups, so it is not surprising that a relatively high percentage of the total species collected in these groups were present in the early spring when air and water temperatures tend to be lower. Conversely, warm-adapted species prevalent within Leptoceridae and Hyroptilidae should have a lower percent occurrence in the early spring and increased occurrences later in the spring.

Fall species. The fall species constituted the smallest seasonality grouping. The most conspicuous caddisfly within fall light-trap samples was *Pycnopsyche antica*. In all panhandle populations sampled, adults of this species were collected from October to December; however, members of the peninsular population at Gold Head Branch were also collected in March, May, and June, suggesting that the life history of this population differs in some significant way from that of the panhandle populations. Aside from panhandle populations of *Pycnopsyche antica*, the only other species restricted to the fall season was *Lepidostoma griseum* (collected only during October). Weaver (1988) reported flight dates from 20 June – 27 September for *L. griseum* across its northern range, suggesting that the Apalachicola ravines population may emerge later in the year than do northern populations.

Extended flight-season species. The greatest number of caddisfly species (68) occurred as adults during both spring/summer and fall seasons. A number of underlying

factors may account for species exhibiting flight periods extending over a wide monthly range. These include: bivoltine life histories, univoltine populations with separate spring and fall cohorts, continuous generations showing no distinct cohort structure, and different emergence phenologies between conspecific populations. An example of differing emergence phenologies between populations appears to be the case with *Cheumatopsyche virginica*, which was collected from March to June on Eglin, but was collected during March, August, and October from the Apalachicola study area. *Psilotreta frontalis* also presents a good example. This species appeared to have a narrow period of emergence (April, May) in most populations sampled, but within some streams in the Apalachicola study area adults also occurred in October, indicating part of the population emerges in the fall.

Table 4-1. Monthly occurrences of adult Trichoptera collected in survey.

Species	Adult Collections (n)	Monthly Occurrence of Adults Collected by Light Trapping (Number of Light Trap Samples)												Flight Season
		JAN (0)	FEB (0)	MAR (20)	APR (26)	MAY (14)	JUN (22)	JUL (0)	AUG (4)	SEP (3)	OCT (15)	NOV (8)	DEC (4)	
ANNULIPALPIA														
Dipseudopsidae														
Phylocentropus carolinus	22			X	X	X	X		X	X	X	X		E
Phylocentropus lucidus	21			X	X	X	X		X	X	X	X		E
Phylocentropus placidus	9			X	X	X	X					X	X	E
Hydropsychidae														
Cheumatopsyche burksi	2			X		X								---
Cheumatopsyche campyla	7			X	X	X								S
Cheumatopsyche edista	15			X	X	X	X							S
Cheumatopsyche gordonae	21			X	X	X	X				X	X		E
Cheumatopsyche petersi	16			X	X	X	X							S
Cheumatopsyche pettiti	25			X	X	X	X		X		X	X		E
Cheumatopsyche pinaca	30			X	X	X	X		X	X	X			E
Cheumatopsyche virginica	19			X	X	X	X		X		X			E
Diplectrona modesta	58			X	X	X	X		X	X	X	X		E
Diplectrona sp. A	3					X	X				X			E
Hydropsyche betteni	2									X	X			---
Hydropsyche decalda	1					X								---
Hydropsyche elissoma	37			X	X	X	X		X	X				S

Table 4-1. Continued.

Species	Adult Collections (n)	Monthly Occurrence of Adults Collected by Light Trapping (Number of Light Trap Samples)												Flight Season
		JAN (0)	FEB (0)	MAR (20)	APR (26)	MAY (14)	JUN (22)	JUL (0)	AUG (4)	SEP (3)	OCT (15)	NOV (8)	DEC (4)	
Hydropsyche incommoda	35			X	X	X	X		X		X	X		E
Hydropsyche rossi	23			X	X	X	X		X		X			E
Macrostemum carolina	10					X	X							S
Potamyia flava	8				X	X	X		X		X			E
Philopotamidae														
Chimarra aterrima	27			X	X	X	X		X		X			E
Chimarra falculata	47			X	X	X	X		X		X	X		E
Chimarra florida	26			X	X	X	X				X			E
Chimarra moselyi	9			X	X		X							S
Chimarra obscura	5				X		X		X		X	X		E
Polycentropodidae														
Cernotina calcea	1					X								---
Cernotina spicata	1					X								---
Cernotina truncona	1						X							---
Cyrnellus fraternus	1						X							---
Neureclipsis crepuscularis	10			X	X	X	X				X			E
Neureclipsis melco	13			X	X	X	X				X			E
Nyctiophylax affinis	1					X								---
Nyctiophylax morsei	10				X	X	X							S
Nyctiophylax serratus	6				X	X					X			E
Polycentropus blicklei	12			X	X	X	X			X	X			E
Polycentropus cinereus	23			X	X	X	X			X	X			E
Polycentropus clinei	1					X								---
Polycentropus floridensis	6				X	X					X			E
Psychomyiidae														
Lype diversa	71			X	X	X	X		X		X	X	X	E
SPICIPALPIA														
Hydroptilidae														
Hydroptila apalachicola	1					X								---
Hydroptila berneri	1					X								---
Hydroptila bribriae	7			X	X	X					X			E
Hydroptila circangula	3			X		X								---
Hydroptila disgalera	5			X	X	X								S
Hydroptila eglinensis	9				X	X					X			E
Hydroptila hamiltoni	4				X	X								S
Hydroptila latosa	15			X	X	X					X	X		E
Hydroptila lloganae	2					X								---
Hydroptila molsonae	1										X			---
Hydroptila novicula	1									X				---
Hydroptila okaloosa	3				X	X								---
Hydroptila parastrepha	3			X		X								---
Hydroptila quinola	22				X	X	X				X	X		E
Hydroptila remita	14			X	X	X	X		X		X			E
Hydroptila sarahae	9				X	X					X			E

Table 4-1. Continued.

Species	Adult Collections (n)	Monthly Occurrence of Adults Collected by Light Trapping (Number of Light Trap Samples)												Flight Season
		JAN (0)	FEB (0)	MAR (20)	APR (26)	MAY (14)	JUN (22)	JUL (0)	AUG (4)	SEP (3)	OCT (15)	NOV (8)	DEC (4)	
Hydroptila waubesiana	15			X	X	X	X		X		X	X		E
Mayatrichia ayama	13			X	X	X	X			X	X	X		E
Neotrichia armitagei	8			X		X	X				X			E
Neotrichia minutisimella	1								X					---
Neotrichia vibrans	1								X					---
Ochrotrichia apalachicola	2					X								---
Ochrotrichia confusa	1			X										---
Orthotrichia aegerfasciella	9				X	X	X		X	X	X			E
Orthotrichia baldufi	2								X	X				---
Orthotrichia cristata	3				X					X				---
Orthotrichia curta	2						X							---
Oxyethira abacatia	11				X	X	X							S
Oxyethira chrysocara	1					X								---
Oxyethira elerobi	2					X								---
Oxyethira florida	2					X								---
Oxyethira glasa	8				X	X	X		X		X			E
Oxyethira grisea	1					X								---
Oxyethira janella	23			X	X	X	X		X	X	X	X		E
Oxyethira kelleyi	13			X	X	X					X	X		E
Oxyethira lumosa	16			X	X	X	X				X			E
Oxyethira maya	14				X	X	X		X		X	X		E
Oxyethira novasota	17			X	X	X	X		X		X	X	X	E
Oxyethira pallida	4						X			X	X			E
Oxyethira pescadori	7				X	X	X							S
Oxyethira savanniensis	6				X	X	X				X	X		E
Oxyethira setosa	1			X										---
Oxyethira verna	1						X							---
Oxyethira zeronia	10			X	X	X	X				X	X		E
Rhyacophilidae														
Rhyacophila carolina	34			X	X	X	X		X		X	X	X	E
INTEGRIPALPIA														
Beraeidae														
Beraea n. sp.	3				X									---
Brachycentridae														
Brachycentrus chelatus	21			X	X	X					X	X		E
Micrasema n. sp.	27			X	X	X	X				X	X		E
Micrasema wataga	9			X	X	X	X				X			E
Calamoceratidae														
Anisocentropus pyraloides	49			X	X	X	X		X	X	X	X		E
Heteroplectron americanum	19			X	X	X	X		X		X			E
Lepidostomatidae														
Lepidostoma griseum	4										X			F
Lepidostoma latipenne	9			X	X		X		X			X	X	E
Lepidostoma serratum	7			X	X	X					X	X		E

Table 4-1. Continued.

Species	Adult Collections (n)	Monthly Occurrence of Adults Collected by Light Trapping (Number of Light Trap Samples)												Flight Season
		JAN (0)	FEB (0)	MAR (20)	APR (26)	MAY (14)	JUN (22)	JUL (0)	AUG (4)	SEP (3)	OCT (15)	NOV (8)	DEC (4)	
Leptoceridae														
Ceraclea cancellata	8				X	X	X		X					S
Ceraclea diluta	8				X	X								S
Ceraclea flava	2				X	X								---
Ceraclea maculata	19			X	X	X	X							S
Ceraclea nepha	5				X									S
Ceraclea ophioderus	1						X							---
Ceraclea protonepha	10				X									S
Ceraclea resurgens	4			X										S
Ceraclea tarsipunctata	9				X									S
Ceraclea transversa	11			X	X	X								S
Leptocerus americanus	5				X	X								S
Nectopsyche candida	1				X									---
Nectopsyche exquisita	15				X	X	X		X					S
Nectopsyche paludicola	40			X	X	X	X				X	X		E
Nectopsyche pavida	19			X	X	X	X				X			E
Oecetis cinerascens	10				X	X	X		X	X				S
Oecetis daytona	3				X		X				X			E
Oecetis ditissa	16				X	X	X		X	X	X			E
Oecetis georgia	27			X	X	X	X		X		X			E
Oecetis inconspicua Complex	71			X	X	X	X		X	X	X	X		E
Oecetis nocturna	9				X	X	X		X		X			E
Oecetis osteni	15				X	X	X			X	X			E
Oecetis persimilis	17				X	X	X		X		X			E
Oecetis sphyra	26				X	X	X		X	X				S
Triaenodes aba	1			X										---
Triaenodes helo	2								X					---
Triaenodes ignitus	50			X	X	X	X		X	X	X	X		E
Triaenodes n. sp.	6				X	X	X							S
Triaenodes ochraceus	1				X									---
Triaenodes perna	5				X	X	X							S
Triaenodes taenia	4				X	X			X					S
Triaenodes tardus	4					X	X							S
Limnephilidae														
Pycnopsyche antica	25			X		X	X				X	X	X	E
Pycnopsyche indiana	1										X			---
Molannidae														
Molanna blenda	38			X	X	X	X		X	X	X	X		E
Molanna tryphena	25			X	X	X	X			X	X		X	E
Molanna ulmerina	7			X	X		X				X			E
Odontoceridae														
Psilotreta frontalis	21			X	X	X	X				X			E
Phryganeidae														
Banksiola concatenata	1				X									---

Table 4-1. Continued.

Species	Adult Collections (n)	Monthly Occurrence of Adults Collected by Light Trapping (Number of Light Trap Samples)												Flight Season
		JAN (0)	FEB (0)	MAR (20)	APR (26)	MAY (14)	JUN (22)	JUL (0)	AUG (4)	SEP (3)	OCT (15)	NOV (8)	DEC (4)	
Ptilostomis ocellifera	2					X	X							---
Ptilostomis postica	5			X	X						X			E
Sericostomatidae														
Agarodes crassicornis	12			X		X	X			X				S
Agarodes libalis	15			X	X	X	X				X			E
Agarodes logani	4			X	X	X					X			E
Agarodes ziczac	23			X	X	X	X				X			E

Observed Flight Seasons (Plecoptera)

The monthly occurrences of stoneflies collected as a part of the biodiversity survey (Table 4-2) revealed several distinct adult seasonality patterns. The *Leuctra* species, members of the euholognathan grouping—what are traditionally called the "winter stoneflies"—occurred as adults only during the coolest months of the year (October-March). It is interesting to note that not all *Leuctra* species typify the "winter stonefly" designation in northern latitudes where a number of species typically emerge during spring and summer. In populations of *Leuctra* spp. throughout northern Florida, however, emergence is only from fall to early spring.

The Systellognatha consisted of mainly spring/summer species. The only systellognathans collected in the fall were *Neoperla clymene* and *Perlesta placida*. *Neoperla clymene*, the dominant stonefly at Gold Head Branch, occurred in spring, summer, and fall samples but was most abundant in May and June samples. *Perlesta placida* mainly occurred as adults in spring and summer, although there was one anomalous record of a single individual collected in November. The other systellognathans showed a narrower seasonal-range in adult occurrence. *Perlinella drymo*

appeared rather early in the spring (March and April) and did not persist long, suggesting that growth and development are more tightly synchronized in this species than that of most stonefly species. *Eccoptura xanthenes* was collected as adults only in late-May and June. The common perlid, *Acroneuria arenosa* was most abundant in June, while *Acroneuria lycorias* adults were more prevalent in April and May. Other stoneflies collected in the survey, but not mentioned here, were either collected only as nymphs or were collected as adults too infrequently to make generalizations as to their adult flight seasons. Adult collection periods for all species of stoneflies known to occur in Florida were summarized in Rasmussen et al. (2003).

Table 4-2. Monthly occurrence of adult Plecoptera recorded in survey.

Species	Adult Collections (n)	Monthly Occurrence of Adults Collected by Light Trapping (No. of Light trap Samples)											
		JAN (0)	FEB (0)	MAR (20)	APR (26)	MAY (14)	JUN (22)	JUL (0)	AUG (4)	SEP (3)	OCT (15)	NOV (8)	DEC (4)
EUHOLOGNATHA													
Leuctridae													
Leuctra cottaquilla James	4			X							X	X	
Leuctra ferruginea (Walker)	3										X	X	
Leuctra rickeri James	1										X		
Leuctra triloba Claassen	2			X									X
Neumouridae													
Amphinemura sp.	0												
Taeniopterygidae													
Taeniopteryx sp.	0												
SYSTELLOGNATHA													
Perlidae													
Acroneuria abnormis (Newman)	1					X							
Acroneuria arenosa (Pictet)	11					X	X						
Acroneuria lycorias (Newman)	5				X	X	X						
Agnetina annulipes (Hagen)	0												
Eccoptura xanthenes (Newman)	3					X	X						
Neoperla carlsoni Stark & Baumann	1						X						
Neoperla clymene (Newman)	12			X		X	X				X		
Paragnetina fumosa (Banks)	1				X								
Paragnetina kansensis (Banks)	1						X						
Perlesta placida (Hagen)	20			X	X	X	X					X	
Perlesta sp. A	1						X						

Table 4-2. Continued.

Species	Adult Collections (n)	Monthly Occurrence of Adults Collected by Light Trapping (No. of Light trap Samples)											
		JAN (0)	FEB (0)	MAR (20)	APR (26)	MAY (14)	JUN (22)	JUL (0)	AUG (4)	SEP (3)	OCT (15)	NOV (8)	DEC (4)
Perlesta sp. B	1						X						
Perlinella drymo (Newman)	21			X	X								
Perlinella zwicki Kondratieff et al.	1					X							
Perlodidae													
Clioperla clio (Newman)	0												
Isoperla dicala Frison	1				X								
Pteronarcyidae													
Pteronarcys dorsata (Say)	2			X	X								

Emergence Study

Trichoptera species found

A total of 492 specimens of Trichoptera representing 12 families, 12 genera, and 13 species were identified from emergence trap samples (Table 4-3). Three species (*Diplectrona modesta*, *Chimarra aterrima*, *Psilotreta frontalis*) accounted for more than 90% of the individuals collected. Only the family Sericostomatidae was represented by more than one species (*Agarodes crassicornis* and *Agarodes logani*). The almost 1:1 ratios in the number of families to species, and families to genera, suggest that interspecific competition and niche overlap may be precluding co-occurrence of closely-related genera and species within very small stream-segments as sampled in the emergence traps. A total of 50 caddisfly species are currently known from the FAMU Farm stream; given this fact, it is apparent that other stream segments are being utilized by many other caddisfly species. Conspicuously absent from the emergence trap collections were the Leptoceridae, in which 11 species have been recorded from light-trap collections made at the FAMU Farm stream. It is likely that these species, and many of the others not collected in the emergence traps, inhabit downstream reaches and do not

readily colonize the upper springrun where species such as *D. modesta*, *C. aterrima*, and *P. frontalis* appear to be the dominant members of the upper-springrun caddisfly assemblage.

Table 4-3. Emergence Trap collections of Trichoptera and Plecoptera.

Species	Specimen Total (n) M=Males; F=Females	Trap No. 1 (n)	Trap No. 2 (n)	Monthly Occurrence
Trichoptera				
1. *Diplectrona modesta*	285(130M,155F)	253	32	ALL
2. *Chimarra aterrima*	110(50M,60F)	109	1	ALL
3. *Psilotreta frontalis*	58(35M,23F)	53	5	Late-MAR, APR, MAY
4. *Molanna blenda*	8(6M,2F)	8	0	FEB, MAR, MAY, SEP
5. *Anisocentropus pyraloides*	7(5M,2F)	4	3	FEB, MAY, JUN, AUG, OCT, NOV
6. *Polycentropus cinereus*	6(6M,0F)	4	2	APR, MAY
7. *Hydroptila sykorai*	5(5M,0F)	5	0	JAN, MAR, MAY, JUN
8. *Lepidostoma serratum*	4(1M,3F)	3	1	MAR, MAY, OCT
9. *Agarodes crassicornis*	4(4M,0F)	2	2	MAY, JUN, JUL
10. *Lype diversa*	2(2M,0F)	1	1	MAY
11. *Agarodes logani*	1(1M,0F)	1	0	APR
12. *Ptilostomis postica*	1(0M,1F)	1	0	MAY
13. *Rhyacophila carolina*	1(0M,1F)	1	0	FEB
Plecoptera				
1. *Leuctra* (females)	73(F)	73	0	OCT, NOV, DEC, JAN, FEB, MAR
2. *Leuctra triloba*	33(M)	33	0	NOV, DEC, JAN, MAR
3. *Leuctra ferruginea*	29(M)	29	0	NOV, DEC, JAN, FEB
4. *Eccoptura xanthenes*	5(3M,2F)	3	2	MAY, JUN
5. *Perlesta* sp.	1(0M,1F)	0	1	JUN

Suborder Annulipalpia. The most abundant species collected was the hydropsychid *Diplectrona modesta* (285 specimens), the dominant hydropsychid within ravine-head springruns throughout the Florida panhandle. Other hydropsychids such as *Hydropsyche* and *Cheumatopsyche* species were not collected within the emergence trap, suggesting that even ubiquitous species such as *Cheumatopsyche pettiti* are unable to colonize habitats with high densities of *D. modesta*. *Chimarra aterrima* was the second most abundant species collected; it occurs in a variety of small streams in northern Florida and is not restricted to ravine springruns. Likewise, the other annulpalpians collected,

Polycentropus cinereus and *Lype diversa*, are both widespread species occurring in many lotic habitats within northern Florida.

Suborder Spicipalpia. The only microcaddisfly species collected was *H. sykorai*, a species recently described in Harris (2002). Known only from specimens collected in Trap 1, this species was not recorded in the survey (Chapter 2) using UV-blacklight, suggesting that it either may not show an attraction to UV-blacklight, or is not active during the early nighttime when light trapping was conducted. None of the 11 hydroptilid species light-trapped at the FAMU Farm stream were collected in the emergence traps. Harris (2002) noted that *H. sykorai* is very similar in overall appearance to *H. ouachita*, which is endemic to Schoolhouse Springs in Louisiana. Assuming *H. ouachita* and *H. sykorai* are sister species, it is reasonable to hypothesize that their parent species was once widespread on the Coastal Plain and became isolated in small headwater springruns on the Gulf Coastal Plain. The other spicipalpian recorded was *Rhyacophila carolina*, a common species in swiftly flowing, spring-fed headwater streams within the Florida panhandle.

Suborder Integripalpia. The 7 species collected are an interesting assortment, including ravine crenobionts (*Psilotreta frontalis*, *Molanna blenda*, *Lepidostoma serratum*, *Agarodes logani*) and other species less restricted in habitat (*Anisocentropus pyraloides*, *Agarodes crassicornis*, *Ptilostomis postica*). Four species (*P. frontalis*, *M. blenda*, *A. crassicornis*, *A logani*) construct larval cases made from mineral materials, while 3 species (*L. serratum*, *A. pyraloides* and *P. postica*) construct cases from plant materials. Species-specific differences in case structure, and larval habits in general, probably allow these species to utilize different benthic microhabitats, resulting in very

fine-scale resource partitioning. Among the integripalpians collected was 1 specimen of *Agarodes logani*, a narrow-range endemic known from only the FAMU Farm stream (Keth & Harris, 1998). The presence of the adult collected in Trap 1 confirms that this species breeds in upper reaches of the springrun.

Trichoptera emergence phenology (Table 4-3, Fig. 4-3)

Adult trichopterans were collected year-round in Trap 1, with peak emergence periods mainly in the spring and fall periods, and relatively little emergence activity in summer and winter. Of the 3 most abundant species, adults of 2 species, *Diplectrona modesta* and *Chimarra aterrima*, emerged throughout the year, while emergence of *Psilotreta frontalis* was confined to the springtime. *Molanna blenda*, *Anisocentropus pyraloides*, and *Hydroptila sykorai* were collected at various times of year, suggesting that these species may also be emerging from the FAMU farm springrun throughout

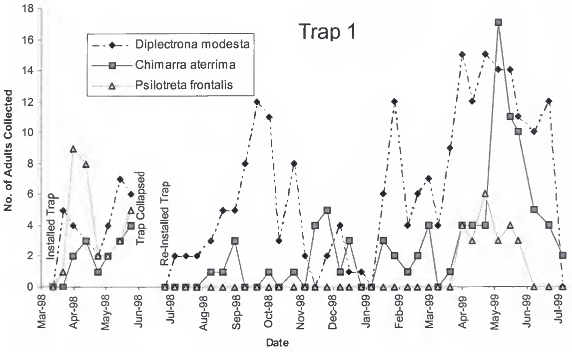


Figure 4-3. Adult emergence of the 3 most abundant caddisfly species collected in Trap 1.

much of the year. In the spring of 1999, emergence peaked for *D. modesta*, *C. aterrima*, and *P. frontalis*. The single size-class of larval collections at the FAMU farm stream and the unimodal emergence indicates that *P. frontalis* has a single cohort that develops in synchronous fashion, resulting in 1 generation per year that reaches maturity in the spring.

The cohort structure and voltinism of *D. modesta* and *C. aterrima* appears to be more complex. *Diplectrona modesta* and *C. aterrima* both showed spring seasonal peaks in emergence, but the almost continuous lower-intensity emergence during other times of year indicates that cohort structure is weak and generations were overlapping and continuously being produced. *Diplectrona modesta* exhibited a secondary, smaller sustained peak in emergence (September-October), suggesting that a fall generation is present. *Diplectrona modesta* was univoltine in both the Tullulah River, a southern Appalachian headwater stream (Benke & Wallace, 1980), and a woodland stream in Tennessee (Cushman et al., 1977). Some *Chimarra* species in North America, including *C. aterrima*, have bivoltine life histories (Wallace & Anderson, 1996). More detailed life history studies involving all life stages are needed before conclusions as to voltinism in these 2 species can be made for the populations at the FAMU farm stream.

Observed sex ratios for the 3 most abundant caddisfly species were slightly female-biased in *D. modesta* and *C. aterrima*, and slightly male-biased in *P. frontalis* (Table 4-5). No clear differences were detected in these 3 species regarding timing of male and female emergence. Earlier male emergence (protandry) has been reported in many aquatic insect orders (Butler, 1984).

Plecoptera species found

A total of 169 specimens, representing 4 species of Plecoptera, were collected in the emergence traps (Table 4-3). The trap catches suggest that only a few species of stoneflies occur in the upper springrun, namely *Leuctra triloba*, *Leuctra ferruginea* and *Eccoptura xanthenes*. The 2 *Leuctra* species numerically dominated the trap catch of stoneflies. Surprising is the fact that these 2 species were collected in nearly equal numbers over the same time period. They appear to occupy very similar niches, which raises questions as to mechanisms that permit their coexistence. Whether these 2 species are similarly distributed within stream sections elsewhere and are able to coexist on a long-term basis is unknown. Perhaps the distribution of these 2 species in Trap 1 was atypical and transitive. Additional emergence trapping is required to address these questions. *Eccoptura xanthenes*, the only perlid from Trap 1, is a signature species of ravine streams in the central panhandle, and its presence illustrates the close biogeographic affinities of ravines in this region with small streams of the southern Appalachians where this species typically occurs.

Plecoptera emergence phenology

Leuctra ferruginea and *Leuctra triloba* exhibited an extended emergence period of nearly 6 months from October through March (Fig. 4-4). During most of this period, emergence of both species was relatively low, but around the beginning of December emergence intensity peaked significantly. The number of *Leuctra* females increased also in one sample taken in late-January, but because females of the 2 species could not be distinguished, the species composition and abundance distribution for females is unknown. Harper (1973) found *Leuctra ferruginea* populations in southern Ontario to

consist solely of individuals with 2-year (semivoltine) life histories from the coolest streams and a mix of semivoltine and univoltine individuals in warmer streams. Embryonic and nymphal growth was found to slow in cool water temperatures and accounted for the differing voltinism observed. At the FAMU farm stream, the rather stable and optimum water temperatures seem to promote steady growth and development and thus favor univoltine life histories.

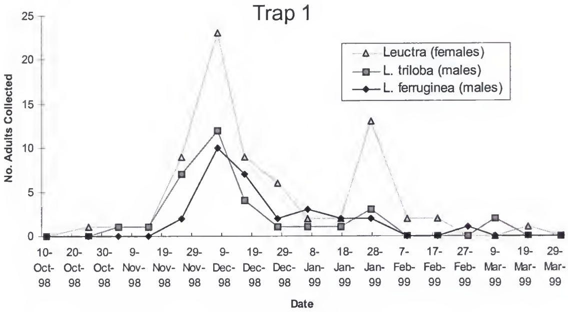


Figure 4-4. Adult emergence of *Leuctra triloba* and *L. ferruginea* in Trap 1.

Eccoptura xanthenes emerged in late-May and early June. The species was semivoltine in a small Kentucky stream (Allen & Tarter, 1985). Determination of voltinism for individuals within the FAMU Farm stream and from other populations in northern Florida requires further investigation. The species displays a well-synchronized late-spring pattern of adult emergence at both the FAMU farm stream and other central panhandle ravines.

CHAPTER 5
SUMMARY AND CONCLUSIONS

Trichoptera and Plecoptera species diversity and ecology were investigated in ravine drainage networks across northern Florida. Central to the study was making an inventory of species diversity in selected areas of northern Florida that possess exemplary ravine ecosystems. The survey data were then used to quantify faunal similarities among sampling stations and provide a community classification of ravine streams based on macrocaddisfly species composition and correlations with geographic and habitat parameters. Survey data were also used to characterize caddisfly and stonefly flight-seasonality within the northern Florida region. Adult emergence phenology of caddisflies and stoneflies at one ravine-headwater springrun was studied using emergence traps. In this final chapter, the first section reviews some aspects of Trichoptera and Plecoptera natural history as it relates to Coastal Plain ravines, and the following sections summarize the study, state major conclusions, and discuss future research needs.

Ravine Biogeography

Trichoptera and Plecoptera, commonly known as caddisflies and stoneflies, respectively, comprise diverse and ecologically important aquatic insects. In the world's temperate zones, both groups are especially well represented in headwater streams and are often dominant members of benthic macroinvertebrate communities. The ecology of benthic communities in headwater streams is closely linked to riparian-forest canopy cover and organic matter inputs. Specialized lineages of Trichoptera and Plecoptera

evolved in unison with eastern deciduous forest, resulting in a diverse and endemic fauna adapted to woodland streams. Species diversification has been magnified by the geographic isolation of populations due to dispersal and vicariance as a consequence of climate changes during the Tertiary and Quaternary. It has been widely postulated that major climatic fluctuations resulted in multiple North/South movements of biota along the major river corridors within eastern North America. The occurrence of ravine streams associated with river valley escarpments likely afforded suitable habitat, thus facilitating movements of woodland-stream taxa. Ravine ecosystems in northern Florida offer suitable habitats for this highly specialized fauna, and because of geographic isolation from similar habitats in the eastern highlands, there occur disjunct and relictual, as well as endemic, elements to the fauna and flora.

In the southeastern United States, refugia for cool-adapted biota are found primarily within areas possessing microclimates that favor the development of mixed mesophytic forest and its associated biota. Ravines, due to mesic conditions created by their sharp relief and spring flow, are important refugia for woodland stream biota. The warm-water aquatic habitats in northern Florida generally do not support caddisfly and stonefly taxa adapted to cool woodland streams; therefore, the spring-fed streams and lush riparian forests found in ravine drainage networks are particularly important for maintaining this biodiversity.

Based on their geomorphology, ravine drainage systems on the lower Coastal Plain of the southeastern United States can be broadly classified into 2 groups: steephead ravines and clayhill ravines. Steephead ravines are a result of groundwater-sapping processes and typically form in deep deposits of coarse sands, whereas clayhill ravines

form in more tightly-packed soils, primarily as a result of scouring from surface runoff. Because of the elevational and moisture gradient in ravines, plant communities are diverse; mid- and lower slopes are especially rich in mesic hardwood species.

Trichoptera and Plecoptera Species Diversity

Species were inventoried by surveying relatively pristine ravine ecosystems in 4 areas across northern Florida (Fig. 1-1). The biodiversity survey methods consisted of repeated collecting of both immatures and adults at 29 sampling stations (Figs. 1-2 to 1-5) throughout several seasons in each study area (Table 2-1). Because adults are required to make species-level determinations for most species, adult collection methods (particularly light trapping) were emphasized. A total of 116 light-trap samples were collected. In order to investigate faunal diversity from a wide array of habitats, collecting was carried out at the upper-most headwaters as well as at various points downstream.

The survey results (Chapter 2), based on more than 16,500 specimen identifications, document a diverse fauna of 138 species of Trichoptera and 23 species of Plecoptera. This represents approximately 70% and 55%, respectively, of the total number of species known in the Florida. From the species inventories, I have identified over 50 species of special interest (Table 2-2) that fit into one or more of the following categories: ravine crenobionts (11 species), species endemic to very limited areas of the lower Coastal Plain (28 species), species that have populations within the study areas that are disjunct from northerly geographic ranges (15 species), species listed by the Florida Committee on Rare and Endangered Plants and Animals as Threatened or Rare (16 species). Besides these species of special interest, many species common to Florida waters were also

documented in the survey. A full accounting of all Trichoptera and Plecoptera species recorded in the survey (Tables 2-3 to 2-6) was presented and discussed.

At least 12 caddisfly species previously unknown to science were discovered in the course of this study. Subsequent to these collections, the following 11 species were formally described: *Agarodes logani* Keth & Harris, 1999; *Hydroptila apalachicola* Harris et al, 1998; *Hyroptila bribriae* Harris, 2002; *Hydroptila eglinensis* Harris, 2002; *Hydroptila hamiltoni* Harris, 2002; *Hydroptila okaloosa* Harris, 2002; *Hydroptila sarahae* Harris, 2002; *Hydroptila sykorai* Harris, 2002; *Ochrotrichia apalachicola* Harris et al., 1998; *Oxyethira chrysocara* Harris, 2002; and *Oxyethira pescadori* Harris & Keth, 2002. All of the newly described species mentioned above appear to be narrow-range endemics, with the exception of *O. pescadori*.

Ravine Headwater Specialists (Ravine Crenobionts)

The small springs and springruns occurring in ravine-heads were found to contain a number of species that appear to be specifically adapted and restricted to those habitats. Species confined to upper ravine-head stream reaches include the caddisfly species *Diplectrona modesta*, *Diplectrona* sp. A, *Beraea* n. sp., *Heteroplectron americanum*, *Hydroptila sykorai*, *Lepidostoma serratum*, *Triaenodes taenia*, *Molanna blenda*, *Psilotreta frontalis*, and *Agarodes logani*. Stonefly ravine crenobionts include *Leuctra triloba* and *Eccoptura xanthenes*. Species such as *Diplectrona modesta*, *Molanna blenda*, and *Heteroplectron americanum* are locally abundant at most ravine-head stations in the panhandle. *Lepidostoma serratum* occurs at ravine heads having small pieces and chunks of clayey substrate at the spring-heads; the larvae are found in association with this unusual substrate. *Diplectrona* sp. A appears to be a new species and is probably endemic

to ravine heads of the Florida peninsula. An undescribed species in the genus *Beraea* was collected at a steephead station on Eglin Air Force Base in the western Florida panhandle. *Beraea* species in North America are exceedingly rare and are confined to seepage-spring muck habitats. *Agarodes logani* is only known from a ravine springrun located in the central panhandle at the Florida A&M University Research and Extension Center. Another new species discovered in this ravine was *Hydroptila sykorai*—the only microcaddisfly species collected in an emergence trap used to capture insects emerging from the upper springrun.

Ravine headwater streams in the central panhandle contain abundant populations of the perlid stonefly *Eccoptura xanthenes* and leuctrid (*Leuctra* spp.) stoneflies. At Gold Head Branch, the perlid stonefly *Neoperla clymene* is the dominant stonefly species throughout the springrun. The central panhandle ravines contain more Appalachian disjunct species than the western panhandle and peninsular study areas, supporting the river-corridor hypothesis for dispersal between Florida and the eastern highlands via the Apalachicola-Chattahoochee-Flint river system. In particular, the distributions of *Eccoptura xanthenes*, *Leuctra triloba*, *Psilotreta frontalis*, and *Trianeodes taenia* indicate that these species most likely entered Florida via this route.

Faunal Elements of Middle and Lower Reaches

The caddisfly and stonefly assemblages of the lower and middle reaches include common species, as well as many species of special interest. The survey revealed that species composition is quite different among the study areas of the 3 regions (western panhandle, central panhandle, peninsula) represented in the study. The middle and lower reaches of the steephead streams surveyed on Eglin Air Force Base in the western

panhandle were found to contain by far the greatest number of narrow-range endemic caddisfly species. The abundance of high-quality steephead ravine streams located in this relatively isolated coastal area has given rise to a unique caddisfly fauna, unparalleled anywhere else on the Southeastern Coastal Plain. The caddisfly fauna recorded from Eglin's steephead streams includes 22 species, out of a total of 92 species, that are narrowly endemic to areas of the lower Coastal Plain. The majority of these species are either confined entirely to streams on Eglin, or, if found outside of this area, are far less abundant, suggesting that the steephead streams on Eglin are the point of origin for much of its distinct caddisfly fauna. Some examples of especially abundant autochthonous endemics are: *Micrasema* n. sp., *Agarodes ziczac*, *Nectopsyche paludicola*, and *Cheumatopsyche gordonae*.

The larger streams sampled in the Apalachicola study area include very few narrow-range endemics, and the caddisfly fauna contains a relatively higher percentage of warm-adapted river species than does any of the other streams sampled. The Apalachicola River appears to directly influence the species composition at stations located near the river. A good example of this is the abundant occurrence of the caddisfly species *Hydropsyche incommoda*. The Apalachicola River appears to have connected the ravine region to the more characteristic warm-adapted fauna—as the high number of leptocerid caddisfly species recorded suggests. The springruns of the Aplachicola steepheads have not developed the highly endemic fauna as seen in the Eglin steephead streams, but do include a number of cool-adapted caddisflies and disjunct species such as *Lepidostoma griseum* and *Lepidostoma latipenne*. The fact that the larger streams in the study area (Flat Creek, Crooked Creek, Sweetwater Creek) experience more variable water

temperatures than the steephead springruns also helps to explain the presence the prevalence of warm-adapted species. Stonefly species of note recorded in the study at downstream reaches include *Acroneuria lycorias* and *Pteronarcys dorsata*. In the panhandle study areas, *Acroneuria lycorias* is the most abundant large perlid in the middle and lower reaches; the populations in Florida are disjunct and largely limited to ravine drainages. *Pteronarcys dorsata*, also a disjunct, was recorded at only a few stations and in Florida the species appears to be sparsely distributed. Specimens of what appears to be possibly 2 *Perlesta* species new to science were recorded from steephead streams in the Eglin area. This suggests that Eglin steephead streams, besides having endemic caddisflies, may also have an endemic stonefly fauna.

Trichoptera Community Structure and Environmental Relationships

The Trichoptera survey of northern Florida ravine ecosystems provides a comprehensive inventory of species diversity from the 4 study areas and shows that faunal composition is very different among the regions and habitats that were sampled. These distinctions were investigated further by analyzing the macrocaddisfly dataset using multivariate statistical methods (Chapter 3). The objectives were to investigate macrocaddisfly community structure and environmental relationships. Abundance data (total number of individuals) for macrocaddisfly species collected at 20 stations were analyzed using the clustering method Unweighted Pair Group Mathematical Averaging (UPGMA) and the ordination technique Detrended Correspondence Analysis (DCA). Similarity among stations in terms of their macrocaddisfly faunas was measured using Spearman's rank order of abundance correlation coefficient.

Community Characterization

The UPGMA cluster analysis resulted in a dendogram (Fig. 3-1) in which branching patterns correspond closely with geography, as well as habitat factors related to stream size and ravine type. Basal splits in the dendogram delineate stations according to geographic region (western panhandle, central panhandle, and peninsula). The central panhandle station cluster further splits into 2 dissimilar clusters that corresponds to large stream or ravine headwater-stream stations. The modestly similar ravine-headwater stations split into 2 clusters corresponding to steephead ravine streams and clayhill ravine streams. Based on this interpretation of the UPGMA dendogram, the following 5 macrocaddisfly communities were identified: Gold Head Branch, Apalachicola steephead streams, clayhill ravine streams, Apalachicola large streams, and Eglin steephead streams. For each community, species composition was tabulated (Tables 3-2, 3-3) and abundance distributions were graphed (Fig. 3-2).

Peninsula region. The Gold Head Branch community is the least diverse—characterized by low species richness and uneven abundance distribution. Factors accounting for the depauparate Gold Head Branch community include: low species diversity of the peninsula, lack of colonization potential from other streams, and possible species extirpations due to historic land-use practices. Two very common habitat-generalists, *Cheumatopsyche pinaca* and *Nectopsyche pavida*, are the most abundant species. Unique to the Gold Head community is *Diplectrona* sp. A, a ravine crenobiont and potential new species to science. The macrocaddisfly communities of the Florida panhandle are much more diverse and do not show the niche-preemption by habitat generalists apparent in the Gold Head community.

Central panhandle region. In the central panhandle the Apalachicola steephead stream community (54 species) possesses a very unusual mix of species that includes a robust assemblage of ravine crenobionts, and northern elements such as *Lepidostoma griseum* and *L. latipenne*, as well as large river species and other warm-adapted fauna. The connectivity of Apalachicola steephead streams with the Apalachicola River clearly impacts community composition; the lack of geographic isolation explains the community's low endemicity, and its watershed connections with the southern Appalachians explains the presence of northern elements. The other central panhandle community comprising headwater ravine stations is the clayhill ravine stream community. By comparison, it has lower species richness (38 species) and is dominated by ravine crenobionts such as *Psilotreta frontalis* and *Diplectrona modesta*; it lacks significant numbers of *Hydropsyche elissoma* and *Chimarra falculata*, which are found abundantly in the panhandle steephead springruns. Large-stream and other warm-adapted taxa are also largely absent in the clayhill ravine stream community. The clayhill ravine community has definite biogeographic affinities with the Appalachian highlands, as indicated by the presence of *Triaenodes taenia*. The Apalachicola large stream community (44 species) has little similarity to the ravine headwater communities and is dominated by hydropsychid and leptocerids; cool-adapted taxa and narrow-range endemics are minor constituents.

Western panhandle region. Eglin's steephead ravine community has a species-rich (62 species) and highly distinctive macrocaddisfly fauna that includes 20 species not recorded from the other communities. Eight of the macrocaddisfly species are narrowly-endemic and 3 of these species are numerically dominant (*Micrasema* n. sp., *Agarodes*

ziczac, and *Nectopsyche paludicola*). The Eglin steephead stream community is heterogeneous, and differences in species composition among stations are significant. However, there is not a large replacement of cool-adapted species with warm-adapted species in the downstream reaches, as is the case in the large streams of the Apalachicola Bluffs and Ravines Region. The Eglin streams maintain their springrun characteristics throughout their course, and as a result a similar set of abundant species are distributed throughout the area's steephead drainages.

Ordination Analysis

The ordination analysis (DCA) resulted in station placements along 2 axes of ecological interest (Figure 3-3). The primary axis appears to be related to a geographic gradient as stations in the western panhandle and peninsula were plotted at opposite ends of the axis and central panhandle stations plotted in the middle. The secondary axis appears to be related to a stream-size gradient. The stream-size gradient was confirmed by separately ordinating western panhandle and central panhandle stations so as to remove the regional affect (Figs. 3-4, 3-5). The ordination analysis, along with the cluster analysis, supports the assertion that macrocaddisfly species composition in ravine ecosystems of northern Florida is controlled by geographic factors related to regional biogeography on a large scale and within-region habitat factors related to ravine type and flow characteristics at a lesser scale.

Flight Seasonality and Emergence Study

The dates when adult caddisflies and stoneflies were collected in the survey were used to characterize flight seasonality (Chapter 4). This basic information is useful in predicting when particular species will be found in the adult stage; however, thorough

investigations into each species life-history traits related to adult emergence phenology and voltinism are needed before the underlying biological causes accounting for the observed flight seasonality can be fully explained. Towards this goal, emergence of adult caddisflies and stoneflies were monitored using emergence traps at the ravine springrun located at the FAMU Farm study area. The collection records obtained in the emergence study also contribute to better understanding species composition of the benthic community at ravine-head springruns.

Flight Seasonality (Tables 4-1, 4-2)

Of the 138 caddisfly species recorded in light-trap samples collected from the study areas, 68 species are characterized as having flight seasons extending over the spring summer and fall, 28 species as having spring/summer flight seasons, and only 1 species as being limited to the fall. The remaining species were not collected in great enough frequency to characterize their flight seasonality. The great majority of caddisfly and systellognathan stonefly species have their peak adult abundance during spring and summer. Differences were noted in the caddisfly taxonomic composition of light-trap samples among samples collected in March, April, May, and June (Fig. 4-2). Total caddisfly species richness was highest in May samples (105 species) when both species richness of Hydroptilidae and Annulipalpia peaked. Integripalpia (other than Leptoceridae) species richness stayed relatively even throughout the spring while the Leptoceridae rose sharply from low species richness in March samples to a peak in species richness in April samples. The seasonal tendencies in emergence among these major groups of caddisflies appear to be related to their temperature adaptations. Among

Plecoptera, *Leuctra* species are present only during the fall, winter, and early spring, while the other stonefly species collected as adults occur primarily in the spring.

Emergence Study

The emergence study conducted at the FAMU Farm ravine springrun provided a more detailed picture of emergence patterns in caddisfly and stonefly populations inhabiting the upper springrun. Emergence traps have an advantage over light trapping, and other adult collection methods, in that adult/larval habitat associations can be more accurately determined. The tent-trap (Fig. 4-1) that was placed over a 4 m^2 stream section near the ravine head was used to monitor emergence at about 10-day intervals for more than a year. The collection results were used to characterize species composition and emergence phenology.

Species composition. The emergence trap collections (Table 4-3) comprised nearly 500 specimens of Trichoptera (12 families, 12 genera, 13 species) and 169 specimens of Plecoptera (4 species). The low caddisfly species richness recorded in the emergence traps, relative to the 50 species recorded at the FAMU farm study area, indicates that the upper ravine-head reach is dominated by a relatively few species. *Diplectrona modesta*, *Chimarra aterrima*, and *Psilotreta frontalis* accounted for more than 90 percent of the trap catch. Other noteworthy records included 2 caddisfly species, *Agarodes logani* and *Hydroptila sykorai*, known only from the FAMU Farm ravine. Among the stoneflies collected, *Leuctra triloba* and *Leuctra ferruginea* were by far the most abundant, occurring in approximately equal numbers. *Eccoptura xanthenes*, a large perlid stonefly common in ravines of the central panhandle, was also recorded.

Emergence phenology. Water temperatures in the upper springrun at the FAMU farm generally stay within about a 3°C range year-round. Not surprisingly, there are various caddisfly and stonefly taxa emerging throughout the year (Table 4-3). Among the most abundant caddisfly species, *Diplectrona modesta*, *Chimarra aterrima* emerge year-round, with a spring-peak in emergence intensity (Fig. 4-3). Cohort structure appears weak and generations appear to be continually produced in these 2 species. In contrast, *Psilotreta frontalis* emerges only in the spring, and appears to have a single well-defined cohort having a univoltine life cycle. The 2 species of *Leuctra* stoneflies each exhibited a prolonged emergence period throughout the fall, winter, and early spring, with a peak in emergence activity in late-November to early-December (Fig. 4-4). The synchronized co-emergence of these 2 congeners within such a small stream-section suggests that they compete closely for resources. The only other stonefly recorded in significant numbers, *Eccoptura xanthenes*, emerges over a relatively narrow time-period from late-May to early-June.

Future Research Needs

Ravine ecosystems offer excellent prospects for additional research related to a wide range of topics. To extend the caddisfly and stonefly research that was reported in this study, additional survey work is needed in other ravine drainage networks, especially outside the areas that were studied. The Econfina Creek steephead streams, which are located between the Eglin Study area and the Apalachicola steepheads, should be surveyed. Besides additional survey work, the biology and ecology of the many species of special interest found in ravine drainage systems should be studied further. Many of these species because of their restricted distributions are particularly vulnerable to

extinction and could be better protected if more is learned concerning their biology and ecology. There are other aquatic insect groups besides Trichoptera and Plecoptera that are very important biotic components of ravine ecosystems and these groups, including Ephemeroptera, Odonata, aquatic Hemiptera, aquatic Coleoptera and Diptera, are still relatively unknown and require study. In addition to basic faunistic and ecological studies, ravines offer interesting opportunities for studies of historical biogeography and investigations into the origins of these distinct faunas. Due to the geographic isolation of ravine populations, molecular studies on genetic diversity in species populations from different drainages are promising avenues of research towards an understanding of dispersal, gene flow, and evolution of ravine biota.

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APPENDIX A
TRICHOPTERA DATA MATRIX

Species	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	F1	F2	F3	G1	G2
	Number of Specimens Identified from each Sampling Station[a]																												
Phylocentropus carolinus									7					2			1	22	4			10			1	2			
Phylocentropus lucidus														1	2				5		3	8	1	1	15	17	1		
Phylocentropus placidus	1	2												4				2			1			1					
Cheumatopsyche burksi		1																								1			
Cheumatopsyche campyla													1	1		10		5				2		30					
Cheumatopsyche edista		2							1				6	3	2	4		2	7			3	6		1	2			
Cheumatopsyche gordonae	12	32	4	40	1	12	112	1		1	16																		
Cheumatopsyche petersi	2	2		1	2	6	5		37	1	2	21																	
Cheumatopsyche pettiti		2	1				2							1	1	2		3	5		3	8	2	1	10	23			
Cheumatopsyche pinaca													26	59		39		108	1	1	1	7	11		2	4		143	651
Cheumatopsyche virginica	2	7	1	2		3	2		5	1		10										1	2						
Diplectrona modesta	208	13	114	62	143	4	107	1						1	34		1	1	101	13	36	11	63	35	163	39			
Diplectrona sp. A																												19	
Hydropsyche betteni																										2	1		
Hydropsyche decalda																												2	
Hydropsyche elissoma	1	1	1	27	5	7	39		60	3	4	4		2				1	24		6	12	13		1		1		
Hydropsyche incommoda	1					1							13	12		153	2	192	64	1	8	371	55	129	1				
Hydropsyche rossi							1						1	7		7		26	27			62	20	10					
Macrostemum carolina	1	20	3	3	6	2	17		55																				
Potamyia flava																7		11				4		10					
Chimarra aterrima	12		15				4		5										17			27	2	1	1	5		9	54
Chimarra falculata	19	98	4	106	7	21	72	30	53	3	9								1	3	28	7	11						
Chimarra florida	4	17	3	3		7			19			1					1		7		4	1		2				4	100
Chimarra moselyi	1	8				22	12		3				6	1				2						1					
Chimarra obscura													1								1		1		4				
Cernotina calcea									1																				
Cernotina spicata																			1										
Cernotina truncona																												1	
Cyrnellus fraternus													1																
Neureclipsis crepuscularis	1		1										1					1			1	1	2	54					

Species	Number of Specimens Identified from each Sampling Station[a]																												
	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	F1	F2	F3	G1	G2
Neureclipsis melco	1	10		2		4	3		10		1																		
Nyctiophylax affinis																										3			
Nyctiophylax morsei	1	6	4	9		2	11		1																				
Nyctiophylax serratus	1						1		1									1											4
Polycentropus blicklei															1			1			1				1	1		10	12
Polycentropus cinereus	7	2	1	1	2	4	13			1					2			5	6			6	5			4	1	1	3
Polycentropus clinei																													1
Polycentropus floridensis	1	19					3		1																				
Lype diversa	31	37	28	29	52	97	151	5	72	3	3	2		3	21		3	14	11	13	4	4	4	1	2	3			
Beraea n. sp.	4																												
Brachycentus chelatus		11	1	22		4	3	1	35	1	1	2										2							
Micrasema n. sp.	3	13	38	79	7	89	13	7	839	3	1	27																	
Micrasema wataga																						3						3	27
Anisocentropus pyraloides	47	6	51	26	60	6	48	2	3		1	1	2	6	11		8	29	35	23	38	36	34		48	19			
Heteroplectron americanum	19	2	30	6	17		2										2	5	1	12	12		13		1	1			
Lepidostoma griseum																			2		3	3	5						
Lepidostoma latipenne															7		2		1		1		2						
Lepidostoma serratum	2				7																				12	10			
Ceraclea cancellata														1		4		15	1				2						
Ceraclea diluta		5		8		3	18		1																				
Ceraclea flava													1					1											
Ceraclea maculata	2			2			1		7	1		1	5	6		1		11				1	5						
Ceraclea nepha														3		2		12											
Ceraclea ophioderus																1													
Ceraclea protonepha						1							12	15		3	1	100				1							
Ceraclea resurgens		7		2								4																	
Ceraclea tarsipunctata													194	73		5		59				2							
Ceraclea transversa														9	3	4	1	33							1				
Leptocerus americanus													3					9							4	6			
Nectopsyche candida				1																									
Nectopyshce exquisita				12			2						9	12				11	7		4	22							

Species	Number of Specimens Identified from each Sampling Station[a]																												
	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	F1	F2	F3	G1	G2
Nectopsyche paludicola	4	101	7	157	1	187	133	13	97	25	66	41																	
Nectopsyche pavida		15					19		6									8				1						378	166
Oecetis cinerascens	1						1		1				7	5				3					1				1		
Oecetis daytona						1	1																					1	
Oecetis ditissa			3	1			1						1						5		1	2			6	2	2		
Oecetis georgia	4		4	3			3		2		1			2		1			4		3	4	1		1	2		43	12
Oecetis inconspicua	19	60	15	33	5	289	153	2	29				14	24	7	6	12	21	70	1	42	5	17		16	13	11	3	8
Oecetis nocturna			1										1	1		2			1		2	1				1			
Oecetis osteni			1			1	1		1					4				4	1		1		1		1	1			1
Oecetis persimilis	1			1		1			1				5	1		6		25	2				3	1					
Oecetis sphyra		1		23	5	102	5		221				23	47		2	1	89	31		3	1	3		13	1	1		
Triaenodes aba																						1							
Triaenodes helo																			2			2							
Triaenodes ignitus	3		2	8		3	3		1				22	15	4	11	2	55	7		4	24	1		6	5	1	130	12
Triaenodes n. sp.		1	3	1					1																				
Triaenodes ochraceus																						1							
Triaenodes perna		1				5	4		2																				
Triaenodes taenia															1										1	5			
Triaenodes tardus													3	1				2											
Pycnopsyche antica		12	11	34		7	14	22	38					2	4			5	37		4	24	1		1			39	32
Pycnopsyche indiana		1																											
Molanna blenda	77	2	41	2	4		1								3				5		2	7	7		23	10			
Molanna tryphena		5		1		2											1	2	16			15				1	1	14	5
Molanna ulmerina	10	3				2																							
Psilotreta frontalis		8			13										14				3	15	22	2	26	2	330	75			
Banksiola concatenata		1																											
Ptilostomis ocellifera									2																				
Ptilostomis postica																1			1						1	2			
Agarodes crassicornis			10				2		35	1									5			1	2		1			4	
Agarodes libalis																			57	2		11	3					144	31
Agarodes logani																									3	2			

Species	Number of Specimens Identified from each Sampling Station[a]																												
	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	F1	F2	F3	G1	G2
Agarodes ziczac	269	268	20	41	68	136	138		8			3																	
Rhyacophila carolina	8	2	2	30			16								6	1			4		5	1	8	2	4	2			
Hydroptila apalachicola																						1							
Hydroptila berneri																						1							
Hydroptila bribriae	2		1	3							1																		
Hydroptila circangula							1		1			1																	
Hydroptila disgalera				2					1		1							1											
Hydroptila eglinensis	2	1	2	1	1		2																						
Hydroptila hamiltoni	1			2			1																						
Hydroptila latosa	2		1	2				1	2		1	1																1	4
Hydroptila lloganae	1			1																									
Hydroptila molsonae							1																						
Hydroptila novicula																											1		
Hydroptila okaloosa	1						2																						
Hydroptila parastrepha				1						1	1																		
Hydroptila quinola	1		1	1			1	1	1				2	1	1	2		1	3		2	1	2		1				
Hydroptila remita				2		1	1			1		1							2		1	4	1						
Hydroptila sarahae	2	1		2		1	2		1																				
Hydroptila waubesiana														1	1	1		2	2		1	2	2		2				1
Mayatrichia ayama				2		1	1		2										1								1	1	4
Neotrichia armitagei	1								1																			2	4
Neotrichia minutisimella																			1										
Neotrichia vibrans																					1								
Ochrotrichia apalachicola			1																1										
Ochrotrichia confusa																								1					
Orthotrichia aegerfasciella	2						1												2		1				1		1		1
Orthotrichia baldufi																			1								1		
Orthotrichia cristata	1													1													1		
Orthotrichia curta																												1	1
Oxyethira abacatia	1		2				1												2			1			1			1	2
Oxyethira chrysocara																													1

Species	Number of Specimens Identified from each Sampling Station[a]																												
	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	F1	F2	F3	G1	G2
Oxyethira elerobi				1					1																				
Oxyethira florida	1																											1	
Oxyethira glasa	1					1																2						2	2
Oxyethira grisea																			1										
Oxyethira janella	2		1	1			1		1					1		2		1	2			3	1		2	1	1	1	2
Oxyethira kelleyi	2		1	3			2	1	1	1	1	1																	
Oxyethira lumosa	2		1	1			1		1						1				3			2	1					1	2
Oxyethira maya	2		1				1		1				1	1				1	1		1	2	2						
Oxyethira novasota				1										1				1	4		2	3	2		2	1			
Oxyethira pallida																						1	2				1		
Oxyethira pescadori	2		2	2																								1	
Oxyethira savanniensis	1			1		1			1																				2
Oxyethira setosa																			1										
Oxyethira verna																			1										
Oxyethira zeronia	2		1	1		1	1		1	1			1	1															

[a] Except for Hydroptilidae species in which case the number of collections are indicated *not* number of specimens.

APPENDIX B
PLECOPTERA DATA MATRIX

Species	Number of Specimens Identified from each Sampling Station																												
	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	F1	F2	F3	G1	G2
Leuctra cottaquilla	1				1			1			6																		
Leuctra ferruginea															1				1		1								
Leuctra rickeri							1																					2	2
Leuctra triloba																							2		4				
Amphinemura sp.																	4												
Taeniopteryx sp.													3																
Acroneuria abnormis	1																												
Acroneuria arenosa				3		2							4	28		4	10	16			3		1						
Acroneuria lycorias				15	9		6		1				6	23	1	1	9	2	11		22	4	8		3	1			
Agnetina annulipes													9																
Eccoptura xanthenes															1		2			2	1		1	4	38				
Neoperla carlsoni																		1											
Neoperla clymene				1									1	1														207	101
Paragnetina fumosa									2				2	1		1		1											
Paragnetina kansensis																					1								
Perlesta placida	2		6	16		3	4	1	2		1		6	12			1	5			4		1		2	1			
Perlesta sp. A					2																								
Perlesta sp. B						1																							
Perlinella drymo	4	6	3	6		1	1		4			1		1				5	6	1	2	13	1						
Perlinella zwicki				1																									
Clioperla clio													1																
Isoperla dicala														9															
Pteronarcys dorsata				3									14					4											

BIOGRAPHICAL SKETCH

Andrew K. Rasmussen was born in Duluth, Minnesota, on July 10, 1964. He attended primary and secondary school in Florida and Wisconsin. In 1982 he graduated from Central High School in Lacrosse, Wisconsin. Following high school he entered the University of Wisconsin-Stevens Point, graduating in 1987 with a Bachelor of Science degree in water resources and biology. From 1987 to 1988 he attended the University of Florida where he graduated with a Master of Education degree in science education. From 1988 to 1991 he was a middle school teacher in Monticello, Florida. After teaching, he worked from 1991 to 1995 as an aquatic biologist at Florida A&M University. In 1996 he enrolled as a graduate student in the University of Florida – Florida A&M University cooperative Ph.D. degree program in entomology. While completing his doctoral research he continued working at Florida A&M University as a research associate in aquatic entomology.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Manuel L. Pescador, Chair
Professor of Entomology and
Nematology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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Professor of Entomology and
Nematology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Ralph W. Flowers
Professor of Entomology and
Nematology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Michael D. Hubbard
Associate Professor of
Entomology and Nematology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Thomas L. Crisman
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This dissertation was submitted to the Graduate Faculty of the College of Agricultural and Life Sciences and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

May 2004

Dean, College of Agricultural and Life Sciences

Dean, Graduate School